SCIENCE EDUCATION SERIES

No. 5

USE OF FERTILIZERS AND MANURES IN SRI LANKA

by

Mervyn W. Thenabadu, B.Sc., M.Sc., Ph.D.

NATIONAL SCIENCE COUNCIL OF SRI LANKA
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FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the National Science Council. The National Science Council Journal provides a medium for the publication of scientific research papers, while "Vidurava," the quarterly science bulletin of the National Science Council, contains scientific articles of a general nature which are of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Science Education Research Committee (SERC) of the National Science Council decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of authors and not necessarily those of the National Science Council.

In conclusion I must thank the Science Education Research Committee of the National Science Council, and in particular its Hony. Director, Prof. K. Jayasena, for the work they have put in to make this project a success.

R. P. Jayewardene
Secretary-General
National Science Council of Sri Lanka

14 November, 1980.

Contents

Chapter 1

PRINCIPLES OF PLANT NUTRITION AND FERTILIZER USE

The object of fertilization and manuring is to ensure that all necessary nutrient elements are available to the crop. At least thirteen of the sixteen essential nutrient elements have to be obtained from the soil and these may be sub-divided as follows:

1. Primary nutrients

Nitrogen, phosphorus and potassium. These primary nutrients are also referred to as the fertilizer elements for they are the elements most commonly needed by plants and also found inadequately supplied in soil.

2. Secondary nutrients

Calcium, magnesium and sulphur.

3. Micronutrients

Iron, copper, zinc, manganese, boron, molybdenum and chlorine.

All plants require essentially the same nutrients, but in different amounts and in different proportions. Any single element cannot be useful to any plant unless all other essential elements are available in adequate amounts. Increasing the quantity of one nutrient element should generally be done with corresponding increases of other elements.

The Need to Use Fertilizers

The removal of essential plant nutrient elements by crops, together with leaching and erosion losses, deplete most soils to the point where commercial fertilizers have to be supplied if profitable yields are to be obtained. The kinds and quantities of fertilizers used have a profound influence on the yield of crops. Each soil in each locality presents a separate problem, hence the need sometimes for varied fertilizer recommendations in different parts of Sri Lanka, as in the case of rice.

From an economic point of view, fertilizers and manures are added to soil to stimulate plant growth and to increase the per unit profit cost of a marketable product.

After World War II, scientists in many countries realized the great need to increase food production in their part of the world. The means of achieving this in a reasonably short time was through the extensive use of fertilizer.

In developing countries like Sri Lanka there is a real need to raise the output and productivity of plantations and farms, especially those of small holdings and small farms. If successful, the total effects will result in an increase in the growth of our national economy.

A clear and quick answer to the types and quantities of fertilizers which could be recommended to farmers for application for the various crops can be determined by research, and are briefly mentioned below.

Determination of Fertilizer Requirements.

Four methods are generally used for determining fertilizer requirements. They are :- 1. Field experimentation 2. Soil tests 3. Plant tests and 4. Biological tests.

1. Field experimentation.

Of the above methods, field experiments or trials are considered the most dependable for establishing fertilizer requirements; and a large number of research publications are available on field experiments conducted in Sri Lanka (Thenabadu, 1973).

2. Soil tests.

This method is less time consuming and cheaper. The soil is treated with chemical reagents to extract from it a quantity of nutrients comparable to the amount which plant roots would extract. These methods vary considerably and various extracting solutions are used for different soils in different climatic zones.

3. Plant tests.

Also known as "tissue tests". This method is the most recent and is based on the assumption that knowledge of the nutritional status of the plant is the best indicator of the availability of a nutrient element in the soil or growth medium. Some work done in Sri Lanka is reported below.

With coconut, leaf analysis methods have been found useful for assessing the nutritional status of palms. However, analysis of nut water has proved a better guide, especially with potassium and phosphorus (Salgado, 1954).

In an attempt to use foliar diagnosis as a check on fertilizer application on sugar cane it was concluded that nitrogen content at five months of age has a direct relationship to yields of cane at harvest (Manuelpillai, 1975).

4. Biological tests.

In this method a test plant or sometimes micro-organisms, usually a fungus, is used to evaluate the fertility of a soil. The convenience of the method lies in the fact that it can be done in small pots either in the laboratory or greenhouse.

Studies on the nutrient status of some coconut soils of Sri Lanka have been made by this method (Paltridge and Santhirasegaram, 1957 a; Paltridge and Santhirasegaram, 1957b; Paltridge and Santhirasegaram, 1957c; and Paltridge and Salmond, 1957).

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Chapter 2

FERTILIZERS, MANURES, GREEN MANURES AND COMPOST

1. Fertilizers

Fertilizers, in contrast to manures, are synthetic materials that differ from organic manures used in early agriculture, because technical knowledge is necessary to obtain good material. Fertilizers are an essential feature of modern agriculture and are materials used to supply mainly N, P, and K either single or in combination.

2. Manures

Manures are of organic origin being derived either from animals or plants. Among these, farmyard manure which was the basis of arable farming from ancient times, is by far the most important. Most manures contain predominantly nitrogen and phosphorus together with lesser quantities of elements like potassium and other macro and micro nutrients.

3. Green manures

In addition to farmyard manures, green manures have been reported beneficial to plant growth due to their ability to supply organic matter to soils, the desirable effects on biochemical processes in soils and on soil conservation, and increased availability of plant nutrients.

4. Compost making

In compost making dung, litter and crop residues are fermented anaerobically.

(a) Heap Method

Composting can be easily done in heaps 1 – 1.5 meters high where waste material, bulky material, dung or urine soaked soil are spread loosely in layers about 30 cm deep. Cattle urine is poured over the material or if it is not available a mixture of fresh dung and water (slurry) can be used instead. It is important to maintain the moisture of the heap around 50 percent, which is optimum, by covering the top with a thin layer of soil to minimize loss of moisture. This will also help to prevent loss of nitrogen.

At the end of two weeks the material should be turned over. This is repeated two weeks later. This operation hastens decomposition and also ensures that the material on the outside of the pile is turned into the centre where it is subjected to a high temperature of around 140°F due to fermentation. The heat thus generated destroys weed seeds and insect pests. At each turning or whenever it is considered necessary, the material should be watered just enough to keep it moist, but not wet. The compost should be ready for use usually in three months. This method is best suited for the dry zone where much protection is not needed.

b) Trench Method

This method is best suited for the wet zone.

When a trench is used for composting, some space must be left at one end to facilitate turning after the initial filling.

The trench or heap should be of convenient length depending on the quantity of material available. It should be enough if the heap is built to a height of three ft within 10-14 days. It is best to have a series of pits or heaps, so that when one is completed another may be started. Addition of a small quantity of fermented material facilitates decomposition in the new heap. It is necessary to have a roof of cadjan or galvanised iron sheets to prevent desiccation during dry weather and drenching and leaching of nutrients during wet weather.

(c) Bin Method

Compost making is ideal for home gardens and small allotments but on a large scale it can be quite cumbersome requiring much labour, time and water. "Bin - Composting" would be a solution to this problem, where composting is done in specially designed bins made of planks or bricks (or bamboos or areca and insulated with gunnies) with raised bottoms having perforations (or bamboos or areca slats placed crosswise at the bottom) so that air could permeate from below the material and create a natural up-draft.

The material when piled in these bins undergo a complete cycle of heat generation without the need for any turning at all. Only an occasional sprinkling of water is required.

A great advantage of the bin method is that it is quicker, because heat is retained for a longer period than when the material is composted in heaps or trenches.

With well insulated bins the weather would not be a problem and could proceed all the year round. As such it could be ideal for the upcountry gardeners.

The drawback of compost making is the amount of labour involved. In some areas an adequate supply of water could also be a problem.

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Chapter 3

FOOD CROPS

Rice

The fertilizer recommendations for rice have undergone many changes since the first recommendation of Joachim in the nineteen thirties (Rodrigo, 1966; Thenabadu, 1970).

Originally three mixtures were recommended for the whole island in the nineteen fifties, and then it developed into a total of eight; two for the dry zone and five for the wet zone with another formulation for sandy soils that are poorly supplied with iron, the *kirimatta* and the peaty soils in both zones. A point of interest is that these recommendations were meant only for "high fertilizer response" varieties.

Further refinements were made in 1964 when the major agro-climatic zones were taken into consideration and recommendations were made on the basis of properties of the predominent soils of each D.R.O. Division in each administrative district (Panabokke, 1964).

Much research has been reported on the response to various kinds of fertilizers, varietal differences in the response to fertilizers (especially to nitrogen), the optimum rate of fertilizer use, and the time and method of fertilizer application (Thenabadu, 1970).

The advantages and disadvantages of using granular-compound -fertilizers for rice, have been reported (Thenabadu *et al.*, 1968; 1970). From *Maha* 1971/72 these fertilizer were recomended as basal or preplant applications for the low-country wet zone (Dept. of Agric. 1971). The Ceylon Fertilizer Corporation has made available to farmers three mixtures in place of the straight fertilizers for basal or preplant application :- V_1, V_2, V_3; and three mixtures for top-dressing :- TDM_1 ; TDM_2; TDM_3 for use in the different parts of the country :-

(i) For the dry zone :

Mixture V_1 as a basal application, with urea as an application to the growing crop.

(ii) For the Mid and Up-country Wet Zone :
Mixture V_2 as a basal application with urea and/or mixture (TDM_1) (containing nitrogen and potassium) applied to the growing crop.

(iii) For the Low-country Wet Zone :
Compound Pelletized Fertilizer (5 : 15 : 15) with urea and/or mixture (TDM_1, TDM_2, TDM_3) applied to the growing crop.

(iv) For areas in the Dry and Wet zones with soils which are deficient in phosphate:

Mixture V_3 as a basal application with urea and/or mixture TDM_1 applied to the growing crop.

Due to subsidies granted by the State, fertilizer use has increased remarkably from 1958 onwards. However, most farmers doubt the full benefits of using the rates recommended by the Department of Agriculture.

From the time the Paddy Lands Act was implemented in 1958 (Govt. Press) loans for purchase of fertilizers (together with credit for other purposes) played a significant role in the development of rice growing in Sri Lanka. Details and history of fertilizer loans and credit for rice within the first ten years or so have been reviewed by Gunadasa (1968).

Recently the Government has been examining the possibility of providing fertilizers free of charge to farmers (SUN, 1978).

Maize

Fertilizer experiments conducted by Kathirgamathaiyah and Dharmarajah (1970) and Hindagala *et al.* (1971) have shown that maize responds well to nitrogen and phosphorus, but not to potassium.

Nagarajah *et al.* (1973) who conducted field experiments on the effects of nitrogen and phosphorus on maize at Bibile, Maha Illuppallama and Sorabora during two seasons *Yala* 1970 and *Maha* 1970/71 have reported the following.

There was a response to only phosphorus at 40 lb P_2O_5[1]/ac at Maha Illuppallama during the first season. During the second season (*Maha* 1970/71) however, there was a very good response to nitrogen at 80 lb N/ac at all three locations. This response was fairly linear[2] up to 80 lb N/ac. A non-statistically significant response to phosphorus up to 40 lb P_2O_5/ac was found only at Bibile.

Coconut

Coconut growing soils of Sri Lanka are generally deficient in nitrogen, phosphorus and potassium and fertilization has increased crop production in the Western and Southern provinces. Fertilizer requirements for coconut in Sri Lanka have been discussed by de Silva *et al.* (1970).

Salgado (1950, 1951) has reported over 200% yield increases to biennal application of 5 lb N, 6 lb P_2O_5 and 10 lb K_2O on the heavily leached lateritic soils of the wet zone, whereas on the comparatively richer lateritic soils of Bandirippuwa the response to fertilizer was much less, being 30% (Salgado 1947, 1951).

Statistically designed experiments laid down at Bandirippuwa during a 30 year period between 1935 and 1965 showed no significant yield response to nitrogen but there was a significant N x K interaction[3]. A combination of 0.75 lb N with 1.5 lb K_2O gave the highest yield while increased response to 1.5 lb K_2O was maximum when nitrogen was increased to 1.0 lb. Increasing nitrogen had a depressive effect on yields at low levels of K_2O (Nethsinghe, 1963).

At Ratmalagara Estate, Madampe, on the other hand it has been found that leaf production and age of flowering were influenced by phosphorus, and from time of bearing a significant yield response was obtained to application of this element. A yield response to potassium on the other hand, was seen at the higher level of 2 lb K_2O per palm,

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1 P_2O_5:-An expression of phosphorus content in a fertilizer, which is a traditional terms used by the fertilizer industry. For calculations the following conversion is used. P x 2.29 = P_2O_5. For further clarification read "The terms phosphate and potash" page 32.

2 Linear response:- A straight line relationship between rate of fertilizer applied and yields when plotted in the form of graph.

3 A relationship between nitrogen and potassium. If the effects of nitrogen vary with changes in the levels of potassium or *vice-versa*, nitrogen and potassium are said to interact and is represented as NxK.

only after 12 years (Nethsinghe, 1961). In contrast to that at Bandirippuwa, this experiment showed a yield response to nitrogen from the twelfth year, a significant N x K interaction from the fifteenth year, and a very significant N x P interaction from the fourteenth year.

In 1956 a subsidy scheme came into operation whereby estates over 20 acres in extent paid only one-third the price, and small holdings less than 20 acres paid half the price for fertilizers.

While most large estates availed of the benefit, many small estates made little use of this concession. This is mainly attributed to ignorance, economic stress, absence of fertilizer stores in the vicinity and to multiple ownership. In many cases the small holders had less than five acres. Further, in recent years many estate owners did not fertilize their lands pending the implementation of the provisions of the Land Reform Act.

A survey conducted by the Coconut Research Board revealed that in 1968 when fertilizer usage for this crop reached 63,209 tons, only 11.5 percent of the small holdings and 55.3 percent of estates larger than 50 acres used fertilizers; and that in general less than 25 percent of the total acreage of the island was fertilized. If the balance land was also fertilized coconut production would undoubtedly have increased much more than 2616 million nuts recorded in 1969.

Potato

Fertilizer studies on potato have been confined mostly to the Rahangala (close to Welimada) and to the Nuwara Eliya areas where this crop is traditionally grown. However, it is also cultivated in the light textured sandy soils or sandy loams of the Jaffna Peninsula during the cooler months of the *Maha* season.

Potato which is referred to as a cold-weather crop responds well to application of well-rotted farmyard manure, compost or green manure which are best incorporated to the soil as basal dressings. This crop is a gross feeder for two reasons: (i) The limited and shallow root system and, (ii) its relatively short growth period. It is a very heavy feeder of potassium; a high yielding crop removing as much as 250 lb K_2O from an acre, of which about 200 lb are generally located in the tubers. This element should preferably be applied as the sulphate because this crop is sensitive to chloride and the latter may even depress yields and quality, by lowering starch content in tubers.

Kandiah and Rodrigo (1954) found 2 cwt Saphos phosphate per acre was sufficient for a crop at Rahangala. They preferred Saphos phosphate in preference to the more expensive super phosphate.

There has been a very striking and steadily increasing yield response to phosphorus 0 – 300 lb P_20_5 per acre at Rahangala; 200 lb P_20_5 giving a response of 5.2 tons per acre (Ponnamperuma, 1958). There was also a highly significant response to 100 lb K_20 per acre on soil with 0.10 m.e. exchangeble potassium. In addition, yield responses of 1.34 and 1.94 tons per acre have been reported to ground dolomite applied at the rates of 5 and 10 cwt per acre respectively. Thus a provisional recommendation was made for the deep, strongly acid, well drained soils of medium texture and good structure at Rahangala.

Cattle manure	10	cwt per acre.
Ground dolomite	10	cwt per acre.
Nitrogen (N)	100	lb per acre.
Phosphorus (P_20_5)	200	lb per acre.
and Potassium (K_20)	50	lb per acre.

For the acid, black, humic loams of Bopatalawa, where nutrients are better supplied, the provisional recommendation was:

Nitrogen (N)	60	lb per acre.
Phosphorus (P_20_5)	100	lb per acre.
Potassium (K_20)	50	lb per acre.

Among different sources of nitrogen, Ponnamperuma (1959) found ammonium sulphate and ammonium sulphate nitrate gave a better response than urea at Rahangala.

Kathirgamathaiyah and Caesar (1964) reported good responses to phosphate fertilizer on the jungle and wet *patana* soils of the Nuwara Eliya district. This response was found to decrease with continued cropping. In contrast there was no response to nitrogen and potassium on virgin soils, but the crop responded to these nutrients with continued cropping. They also reported a very high response to cattle manure, there being no response to inorganic fertilizers without cattle manure.

Studies in farmers' fields on fertilizer response of potato in the Rahangala area by de Vaz and Thenabadu (1972) during two seasons showed that fertilizers in excess of that recommended by the Department of Agriculture had little effect on yields. It was found that dolomitic limestone was as good as N.P.K. fertilizers in increasing yields over the no fertilizer, control treatment.

Cassava (Manioc)

Not much work on the fertilization of Cassava (Manioc) has been reported from this country. It is known to rapidly exhaust the soil, a feature it shares with most rapidly growing carbohydrate yielding crops.

According to work reported from the Department of Agriculture (1957) there has been no response to phosphorus and potassium, although 20 lb N/ac has produced 16,411 lb/ac compared to the control treatment which produced only 12,781 lb.

Sweet Potato

Potassium is by far the most important nutrient element for this crop, next is nitrogen. As far as nutritive values[1] are concerned, the latter element and phosphorus are important, as they increase the carotene content of the tubers.

The response to manuring and methods of planting of sweet potato in Sri Lanka have been reported by Gunawardene (1954).

Sugar Cane

An adequate supply of nitrogen is essential for high yields of sugar, but an excess may be detrimental. Sugar yield is the product of cane yield x sugar content. Cane quality can deteriorate with excess rainfall or irrigation.

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1. Nutritive Values :- the values of serving to nourish; the values of affording nutriment.

The efficiency of the use of applied nitrogen in the presence of optimum amounts[1] of phosphorus and potassium were investigated by Manuelpillai (1975a) at Kantalai, in an experiment with four levels of nitrogen (0;60;120; and 150 per acre as ammoinum sulphate) and in three applications.

The 60 and 120 lb N per acre treatments showed the highest number of tiller counts. The latter treatment showed a high percentage of stalk count. The highest weights of cane increased in treatments that received the split application[2].

Yield of cane was superior in plots that received nitrogen in split applications compared to those receiving a single application. Supplying 150 lb N per acre in three split applications gave the highest yield of 37.89 tons cane per acre.

Manuelpillai (1975b) has also reported an investigation on foliar diagnosis as a check on fertilizer application on sugar cane and found that nitrogen content at 5 months of age has a direct relationship to yield at harvest, provided phosphorus and potassium are adequately supplied.

From work reported above Manuelpillai has also observed that excess nitrogen, lowers the purity of the juice in cane which has detrimental effects on the percent recoverable sugar in cane.

Vegetables

Most vegetables are short duration crops and reach maturity within two months or less. Due to this reason adequate nutrients should be available for their growth during this short period. It has been generally found effective to use (organic) manures together with (inorganic) fertilizers in vegetable growing. The only problem caused by the former is that it may carry plant diseases, weed seeds and encourage pests.

1. Optimum amounts:- The best or most suitable or favourable amounts for high yields.
2. Split applications :- Where a basic dressing of fertilizer is given before planting time and followed by further doses later during the growing season.

Leaf Vegetables

Organic manures should be applied at or before planting. It is rarely that adequate time is available for the decomposition of green manures applied for vegetable beds. Hence it is best to apply well rotted farm yard manure, compost or poultry manure at least once per season. Such organic manures are extremely helpful on sandy soils due to their ability to retain moisture, and on clay soils because they increases porosity and improve structure of soils.

Generally, leaf vegetables require fairly large quantities of nitrogen, but some crops like cabbage and lettuce require adequate amounts of potassium (sometimes even more potassium than nitrogen). Some plants like spinach respond to application of fresh cattle manure and urine although the dried material is better with most other leaf vegetables.

Inorganic fertilizers should be applied in two doses: 1. about two weeks after sowing or transplanting and 2. one week before flowering. The rate of application of the mixture given below should be one cwt/acre or a quarter cwt/ 100 sq.ft. at each application.

The fertilizer mixture is as follows :-

Ammonium sulphate	6	parts.
Concentrated Superphosphate	1	part.
Muriate of potash	2	parts.

Urea may be substituted for ammonium sulphate, but only half the quantity of the latter need be used. (Urea has 45–46% N as against 21% in ammonium sulphate).

Fertilizer studies of some other vegetables are given below :-

Cabbage

Results of two experiments conducted at Rahangala (in the Welimada area) show that cabbage responded to nitrogen and phosphorus fertilizer. There was no response to potassium, although cabbage is described as a grossfeeder of both potassium and nitrogen (Kathirgamathaiyah, 1965).

Bean

Results of two experiments with bean conducted at Rahangala, showed that phosphorus seemed to be the nutrient element needed for bean in that area. There was no effect of nitrogen on yield although a small dressing of the element at the start was found beneficial for quicker initial growth and slightly higher yields (Kathiragamathiyah, 1965).

Chilli

Early experiments in the dry zone have been reported by Joachim and Paul (1938) and by Joachim *et al.* (1939).

Recent experiments with a chilli selection from Maha Illuppallama, conducted at Gannoruwa (Peradeniya), showed that there was a response to nitrogen at 40 lb element / acre. These results were similar to that of earlier experiments of Joachim and Paul (1938) with the varieties Tuticorin and Mathakala in that there was a response only to nitrogen (Thenabadu *et al.* 1974). Responses to 40 lb N/ acre with the variety Myliddy have been also recorded at Tinnevely (Director of Agric. 1960).

In an investigation on the interaction of fertilizer levels and plant density at Gannoruwa conducted during three seasons Gunawardena and Pereira (1975) found a significant increase in yield to fertilizer application and stated that "the indications are that a much higher level of fertilizer than that currently recommended could be used."

Current recommendations of the Department for chilli/acre are as follows :-

1. Irrigated chilli

   5 tons cattle manure

   1 cwt concentrated superphosphate

   ½ cwt ammonium sulphate

   ½ cwt Muriate of potash.

This is to be supplemented with top-dressings at the following times and rates per acre :-

Two weeks after transplanting –
½ cwt. Ammonium sulphate.
Five weeks after transplanting –
½ cwt. Concentrated superphosphate.
¼ cwt. Ammonium sulphate.
¼ cwt. Muriate of potash.
Eight weeks after transplanting–
½ cwt. Ammonium sulphate.
Twelve weeks after transplanting–
¼ cwt. Ammonium sulphate.

(ii) **Rainfed chilli** – Basal dressing :-

½ cwt. Ammonium sulphate per acre.
1 cwt. Concentrated superphosphate per acre.
½ cwt. Muriate of potash per acre.

Supplemented with fertilizer top-dressings at the following times and rates per acre :-

Four weeks after planting –
1 cwt. Ammonium sulphate.
Eight weeks after planting –
½ cwt. Ammonium sulphate.

After each application of fertilizers a light irrigation should be given.

Onion

The results of two experiments conducted at Kundasale with shallot showed a significant response to 30 lb nitrogen/acre, but there was neither a response to phosphorus and potassium, nor any NxPxK interaction[1]. (Thenabadu *et al.,* 1975).

1. A relationship between nitrogen, phosphorus and potassium. Also see foot note on page 9.

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Chapter 4

INDUSTRIAL CROPS

Cotton

Until recently cotton was a rainfed crop in Sri Lanka, and in areas like Hambantota District it was the chief cash crop. Some of the early work on cotton manuring have been reported by Joachim (1937), Joachim and Paul (1937) and Joachim and Pieris (1937).

For successful cultivation of cotton, nitrogen is the most important nutrient element. Under irrigation however, consistent responses to nitrogen in particular have been striking in the *Yala* season (Dias, 1969). Nitrogen either as ammonium sulphate or urea, has given responses up to 80 lb/ac; applied in two equal split doses, one at sowing and the other at flowering. With the variety HC 101 heavy doses of the element sometimes lead to excessive vegetative growth at the cost of yield. No direct responses to phosphorus or potassium have been recorded.

Recommendations of the Department of Agriculture for rainfed cotton, variety HC 101, are as follows :-

Ammonium sulphate	100 lb/ac
Concentrated superphosphate	100 lb/ac
Muriate of potash	50 lb/ac

Incorporation of 3–5 tons cattle manure/acre to soil at final preparation is beneficial. The cotton plant is known to react to physical, chemical and biological conditions of the soil, Thus best results are obtained by balancing these variables[1] at their optimum to suit the physiological requirements of the cotton plant.

1. Factors for plant growth that are liable to vary or change at a particular location. It is a characteristic that can be classified.

Rubber

Soil requirements of rubber are lower than those of other tree crops liike coffee, cocoa or coconut. Further, very little nutrients are removed n the latex, particularly with the old type of low-yielding seedling trees. However, yield depends on the healthy growth and development of the tree and its foliage, and this depends on efficient use of fertilizers. For this reason more attention is paid to the manuring of young, seedling trees than to mature trees. With immature trees fertilizers are needed to accelerate their growth and maturity. Hence the importance of fertilizing in the early stages of growth.

According to recommendations of the Rubber Research Institute however, all immature areas must be adequately fertilized; and all mature areas, at least on the virgin bark, must be fertilized adequately (Silva 1970 a). According to Advisory Circular No: 66 of 1959 rubber lands in Sri Lanka are divided into six groups.

The results of field experiments conducted up to 1970 have enabled the following conclusions (Silva, 1970).

1. Nitrogen deficiency is fairly wide spread and if extra nitrogen applications are not given, it may lead to at least a 10% set back in growth on 90% of the clearings, though in certain experiments omission of nitrogen has resulted in a 25% set back.

2. Phosphate is essential for growth and yield and nitrogen useful for growth.

3. Potassium deficiency is reported in some soils, although not of general occurrence. It is recorded mainly in areas intrinsically poor in minerals capable of supplying this element, or which are exhausted by intense cultivation.

4. Growth responses of the order of 15–30% due to NPK treatment compared to treatment of phosphate alone have been obtained. Therefore the use of phosphate alone as a fertilizer for rubber is not recommended.

5. Magnesium deficiency is on the increase and is severe in the clone PB 86. It is likely that the use of high potash mixtures may have accentuated this. There is a possibility that the full beneficial effects of fertilizing with NPK mixtures may not be attained due to latent magnesium deficiency.

Based on these findings three mixtures containing N:P:K: and Mg have been recommended for rubber in Sri Lanka. These mixtures and their compositions are as follows:–

1. R.4:6:2+Mg

100 lb of	sulphate of ammonia	(20.6% N)
100 „ „	rock phosphate	(28.5% P_20_5)
20 „ „	muriate of potash	(50 % K_20)
20 „ „	commercial Epsom salt	(16 % Mg0)

2· R. 4:6:3+Mg

100 lb of	sulphate of ammonia	(20.6 % N)
100 lb „	rock phosphate	(28.5 % P_20_5)
30 „ „	muriate of potash	(50 % K_20)
30 „ „	commercial Epsom salt	(16 % Mg0)

3. R. 4:6:5+Mg

100 b of	sulphate of ammonia	(20.6% N)
100 „ „	rock sulphate	(28.5% P_20_5)
50 „ „	muriate of potash	(50 % K_20)
50 „ „	commercial Epsom salt	(16 % Mg0)

The rubber growing soils of the country have been grouped into six soil series (Silva, 1970 b) and the above three mixtures are recommended as follows :–

Soil Series	*Fertilizer Mixture*
Perambe	R. 4:6:2+Mg
Homagama	R. 4:6:5+Mg
Agalawatta	R. 4:6:3+Mg
Ratnapura	R. 4:6:3+Mg
Matale	R. 4:6:5
Boralu	R. 4:6:3+Mg

As mentioned earlier the quantity of any fertilizer mixture depends on the age of the plant and a manuring schedule has been recommended (Silva, 1970 b).

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Chapter 5

STIMULANTS

Tea

The explorations of fertilizer requirements of tea, in Sri Lanka, were started during the period 1928 – 1930, about four years after the Tea Research Institute was established (Foster – Barham, 1963).

The first experiments were designed to evaluate the efficacy of the three nitrogenous fertilizer used at that time viz. blood meal, cyanamide and ammonium sulphate. Fertilizer application for tea in Sri Lanka has been reviewed by Bhavanandan (1970).

Standard fertilizer mixtures for tea, were introduced only during World War II until which time there were wide and varied mixtures, the compositions of which were without any rational basis.

In 1948 it was concluded that: (1) Nitrogen could be economically used up to 80lb/ acre. Potassium was recommended at 3.5 lb/ 100 lb crop harvested. (11) The organic forms of N offered no special benefit or advantage over the inorganic forms, (III) Weather conditions and presence of foliage, were important for optimum yields. According to Eden (1949) 100 lb made tea removed 6.38 lb N, 1.55 lb P_20_5 and 3.47 lb K_2O.

Lamb (1953) has presented a guide in which the recommended quantities of T 500 mixture are shown for different cropping levels. Tea is a leaf crop and therefore the most important fertilizer element is nitrogen. Tea yields are in general closely related to the amount of this nutrient applied. The full effect of the application of nitrogen may not be seen in the first year itself, but the effect is cumulative during the pruning cycle and even from cycle to cycle as shown by Eden (1949), where the mean nitrogen efficiency increased from 1.1 in the first year to 5.0 in the third year, in the third cycle; and from 0.1 to 4.1 from the first to the fourth year in the fourth cycle

Vegetatively – propagated Tea

Results of the initial fertilizer trials on vegetatively – propagated, low grown tea have been reported by Joachim (1964) and Fernando *et al.* (1969).

Of the elements tested only nitrogen has given a consistent response, there being a response up to 225 lb element per acre per year. It has also been found that the best yields were obtained when the nitrogen was given at eight weekly intervals.

The response of fourteen fertilizer trials in the low country located at Opanaike, Deniyaya, Morawaka, Nakiyadeniya, Talgaswela and Ratnapura with vegetatively propagated tea has been reported by Wettasinghe (1972).

The indications are that responses to nitrogen occur from 160 to 480 lb per acre per year. In most experiments however, it was found that the return was below 2 lb made tea per lb of nitrogen above the level of 240 lb of the nutrient.

No consistent response was obtained in an experiment designed to test 3 types of nitrogenous fertilizers. Either ammonium sulphate was superior to both urea and calcium ammonium nitrate, or there were no differences between them.

Incorporation of lime to soil was found to depress yields, while the response to phosphorus was only up to 30 lb per acre per year. There was no response to both potassium and magnesium on these soils of the lowlands.

Tobacco

The economics of tobacco growing depends on both yield as well as quality of the product. Thus increase in yield must not be at the expense of quality like burning. With flue-cured tobacco, especially, too much nitrogen can limit profit as much as can too little of the element. (Attygalle and Jayanetti, 1955; Kandiah and Rodrigo, 1955).

Excess N appears to make the leaf coarse in texture and to cause "puckering" in the leaf. On the other hand inadequate nitrogen tends to retard maturity and produces a cured leaf of undesirable colour, poor texture and other characteristics associated with low quality.

From investigations in the Gal Oya Valley, Kandiah and Ratnasingham (1962) have recommended the following :

(a) For sandy loams and sandy soils a mixture containing N/P: N/K: P/K in the ratio of 2.5 : 3.1 : 12.5.

(b) For loams and heavier types the corresponding mixtures in the ratio 2.0 : 2.5: 12.5.

From the results of Beedi tobacco trials conducted at Hambantota, Jayanetti (1968) concluded that the variety 3–1 was more promising than K–20 in this district and that the results of nitrogen responsiveness varied according to the weather conditions. A progressive response up to 120 lb N per acre (as ammonium sulphate) was obtained in yield of cured leaf. Above 60 lb however, the yield increase was not proportionate to the rate of nitrogen applied. Under drought conditions 60 lb N per acre appeared to be optimum.

These was no response to phosphate or potassium fertilizers.

In an investigation on forms and levels of nitrogenous fertilizers for flue-cured tobacco in the dry zone, Jayanetti, and Sabanathan (1968, 1969) reported the following:

1. Nitrogen applications at 20 lb element per acre increased yield and improved leaf quality over the no-nitrogen treatment.

2. Application of all nitrogen at planting seemed satisfactory at Hingurakgoda. At Gal-Oya further studies were necessary.

3. Equivalent amounts of nitrogen given as ammonium sulphate, ammonium sulphate nitrate, ammophos or urea showed no differences in the leaf produced. On this basis they stated that urea which s used extensively in rice cultivation could also be used in tobacco cultivations.

Rogers and Joachim (1941) have described the results of experiments on the manuring of cigarette tobacco in Sri Lanka.It may be speculated whether this early work has much meaning in the light of the newer varieties of cigarette tobacco currently in use.

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Chapter 6

GRASSES AND GRASSLANDS

In grassland farming the greatest amount of grass has to be produced in the shortest possible time. This grass has to be also of high nutritive value. Generally, the nutritive value of grasses decline with maturity. Grass is still the cheapest food for ruminants and in the tropics yields as high as 75,000 lb dry matter per acre are possible.

The effect of large applications of urea on the growth and yield of an established pasture of *Brachiaria brizantha* has been reported by Appadurai and Arasaratnam (1969); while Sivalingam (1964) has reported a study of the effect of nitrogen fertilization and frequency of defoliation on yield, chemical composition and nutritive value of three tropical grasses. Much of the available information up to the mid-sixties has been presented by Appadurai (1968).

From a study of the agronomic aspects of Kikuyu grass Andrew and Jayawardena (1971) reported that this grass was a heavy feeder and therefore if the soil is not rich in plant nutrients, application of fertilizer or cattle manure is necessary.

Fertilizers affect growth and yield of grasses while they improve their nutritive value. Keith and Ranawana (1971) have reviewed available information on the nutritive value of Kikuyu grass, especially that growing at Ambawela.

The potential of three important fodder grasses of Sri Lanka, Pusa giant Napier, Guinea B and Setaria have been reported by Goonawardene and Appadurai (1971, 1972). All three were reported as high tonnage varieties which offered considerable promise in the mid-country areas and have to be therefore well supplied with nitrogen, eg. 300 lb per acre.

Sivasupiramaniam, Sitamparanathan and Appadurai (1973) commenting on the extremely low productivity of native pastures attributed this largely to the very low level of soil fertility caused by sheet erosion over the past several decades. In an attempt to establish pastures they found applications of calcium, phosphorus and sulphur resulted in a significant increase in yield of the pioneer crop or Sorghum or Sunhemp.

The cheapest method by which pasture could be supplied with the required nitrogen for its growth is by growing it in association with legumes. In later studies Sivasupiramaniam *et al.* (1974) found *Paspalum dilatatum* responded to nitrogen fertilizers in a linear fashion up to 3 cwt/ac/yr., giving a dry matter yield of 10,000 lb/ac/yr.

Appadurai and Goonewardena (1974) have reported the effects of nitrogen and defoliation on the production of *Brachiaria ruziziensis,* and concluded that this grass is of value for the mid-country wet zone, and that under adequate nitrogen fertilization and close but less frequent defoliation it is capable of giving high yields of herbage dry matter, of reasonably good feeding value.

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Chapter 7

SLOW RELEASE NITROGEN FERTILIZERS NITRIFYING INHIBITORS AND COATED FERTILIZERS

Slow Release Nitrogen Fertilizer

Most nitrogenous fertilizers contain nitrogen in a quickly available, inorganic form. When they are applied, response to nitrogen can be seen very quickly on plants but the effect also quickly disappears. Accordingly, the number of top dressings increases if a high yield is required. Such quick acting fertilizers are easily leached out by heavy rain. For instance, about half the nitrogen in the ammonium form (which is adsorbed by soil particles) may be lost by leaching from some soils during the growing season. Also, if a heavy dressing of inorganic fertilizers is applied as a basal dressing, the high concentration of salts may sometimes damage or inhibit seed germination. Mechanization of agriculture also requires a special kind of fertilizer that maintains its effect for a long time.

1. Their effect should be continuous and slow but partly controllable by variation of granule size, placement and other means.

2. When they are applied in large amounts, there should be no harm to germination and root development.

3. They should be stable and remain dry during storage and transportation.

A new type of slowly-available or slow-action nitrogen fertilizers has been developed since the sixties. Many organic fertilizers (e.g. seed-cake, farm manure, compost) contain nitrogen in a form which slowly decomposes, but these products of modern chemical industry can be handled as easily as their commercial fertilizers. At present, these fertilizers are rather expensive, (especially in countries like Sri Lanka) so that they are often prepared in mixed forms with ammoniacal or nitrate nitrogen fertilizers. For such fertilizers, "controlled release nitrogen fertilizer" is used as an alternative name.

Many of these fertilizers are the condensation products of urea and aldehydes and their decomposition is often dependent on the kind of condensation. When our urea plant is functional, these fertilizers may be manufactured in Sri Lanka.

The processes of decomposition of these fertilizers can be divided into two main groups, one due to the action of microbes and requiring a minimum temperature of 10°C, the other due to water hydrolysis which operates at all normal soil temperatures. For example, the Ureaform group and CDU are broken down by microbial action and are unaffected at temperatures below 10°C, while Urea-Z IB and Urea-furfural compounds are decomposed by hydrolysis.

Another approach to control the release of nitrogen from simple inorganic nitrogenous fertilizers (e.g. ammonium salts and urea) is to add chemicals which suppress nitrification in soil. These are the nitrifying inhibitors. A third method of controlling nitrogen release (including that from nitrates themselves) is to coat the fertilizer granules with a layer of semi-permeable material, which only allows the inorganic salt to dissolve or decompose slowly.

Nitrifying Inhibitors and Coated Fertilizers

As an alternative to using slow release nitrogen fertilizers, nitrifying inhibitors mentioned earlier can be used. These are added to nitrogen sources in minute quantities to slow down nitrogen release by depressing the activity of nitrifying bacteria.

There has been some success reported in the prevention of loss of nitrogen by leaching as nitrate, which allows the use of cheaper fertilizers such as ammonium sulphate or urea as slow releasers of nitrogen.

Recently, controlled release of plant nutrients by coating fertilizer granules with water-resistant or semipermeable material has been used. Materials investigated as coating agents include various plastic resin substances, waxes, paraffin compounds, asphaltic mixtures and sulphur. Coating however adds to the cost of the final product.

Among the advantages offered by coated fertilizers is the slow release of plant nutrients over a period of several weeks or months. This also prevents leaching losses of nutrients early in the growing season and subsequent deficiencies as the crop reaches maturity. In addition luxury consumption of nutrients by plants, salt injury, hygroscopicity and other undesirable effects can be prevented by coating fertilizers.

Factors affecting the rate of release of nutrients from coated fertilizer granules can be summarized as follows.

1. Rate or time of release of nutrients can be controlled by the thickness of the coating.

2. Soil conditions such as acidity or alkalinity, bacterial activity and soil texture have little effect on the release of nutrients.

3. Soil moisture required for normal crop growth also has little effect on the rate of release of nutrients

4. An increase in temperature accelerates the diffusion of nutrients out of granules.

5. The rate of release of nutrients from coated fertilizers is related to the solubility of the coating. The release rate from coating of low solubility is naturally slower than that from coating of high solubility.

Chapter 8

THE TERMS – "PHOSPHATE AND POTASH"

The terms "phosphate" and "potash" were first used in the distant past when chemists expressed chemical analysis of rocks and soils as oxides, Fe_20_3, Al_20_3 etc. With time this practice continued because this traditional method was found desirable in expressing the composition of fertilizers as well.

Because expressing phosphorus and potassium as P_20_5 and K_20 respectively would cause problems in communication, attempts have been made to express these as P and K respectively, in the elemental form, like nitrogen N and other nutrients, which are expressed as such. The relevant conversion values are given below :–

P x 2.29	=	P_20_5
P_20_5 x 0.44	=	P
K x 1.20	=	K_20
K_20 x 0.83	=	K

Chapter 9

PROFITABILITY OF FERTILIZER USE

Profits from fertilizer use depend on several factors such as the crop, the season, the soil and the efficiency of management.

When one considers the economics of fertilizer use one should distinguish between the fertilizer dose that gives the highest yield and that which is most profitable. This depends on the price one gets from the crop and the cost of fertilizers one uses.

Yield response :

The yield response to fertilizer follows the Law of Diminishing Returns. The first application of fertilizer gives only a small response because the soil retains more nutrients than the plant absorbs – in short the soil competes with the plant. Following the addition of a minimum effective dose there is a quick and large response. This response then slows down as the metabolism of the plant reaches a point of saturation; and beyond this point further addition of nutrients could have a deleterious effect shown by a negative response.

Figure I*a* depicts a general type of "yield increase curve". It will be noted that yield increase from the first 30 lb of nitrogen is greater than that from the second 30 lb and the yield increase for each additional 30 lb becomes progressively smaller, until a point is reached when additional fertilizer does not increase yield any further.

Figure I*b* depicts the manner the cost of fertilizer and of handling it varies as the quantity used increases.

Profits :

Final profits will be the difference between the returns from the crop and the cost of producing it. Combining Figures la and 1b gives figure 1c, from which can be seen how costs and returns vary as the amount of fertilizer is increased. In practice, only the costs that change with different amounts of fertilizer need to be considered in deciding how much should be used. Profits are now easily estimated by checking Figure 1c because the difference between the returns curve and the cost curve (the shaded area) represents profits from the use of fertilizer.

The rate of fertilizer that will give the most profit per acre is an important consideration. The point at which the yield value curve and the cost curve are the greatest distance apart is the rate which will give maximum net profit per acre. In the example shown, this rate is 90 lb N/acre, and as fertilizer use is increased from this point, profits will decrease.

Even a high response to supplied fertilizer will be of little use if the price relation between fertilizers and produce is unfavourable, making fertilizer use unprofitable. This condition is most likely in remote places where fertilizers have to be transported over long distances.

In developing countries like Sri Lanka the state endeavours to improve the price relations and profits from fertilizer use by granting subsidies as an incentive to farmers to use fertilizers.

Farmers will not use fertilizers unless they are convinced that these would give profits. A scientist who wishes to know how a particular crop should best be fertilized in a particular soil under a given set of conditions would first conduct a factorial experiment with a minimum of three levels of each nutrient which would enable an economic analysis of the data.

Best Rate :

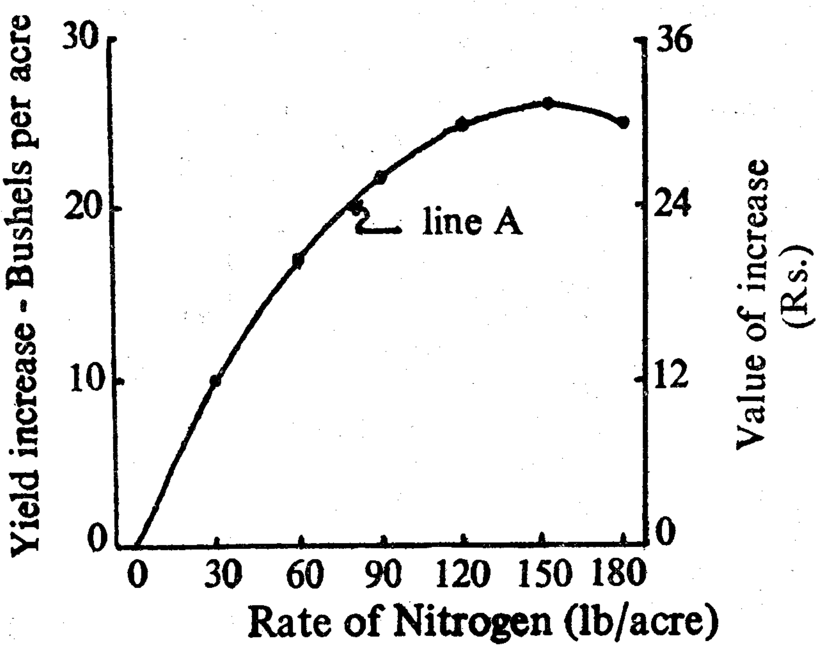
The rate used to obtain maximum yields is not the most profitable as seen in figures 1a, b and c; and a farmer will obviously fertilize his field at a rate that gives most profit/acre. If adequate capital is available to purchase fertilizer, investing to obtain maximum profit is not a problem. On the other hand, if adequate capital is not available it would be advisable to fertilize at a rate short of maximum net profit. That is, in short, to invest the available money on as many acres as it will cover.

Risks :

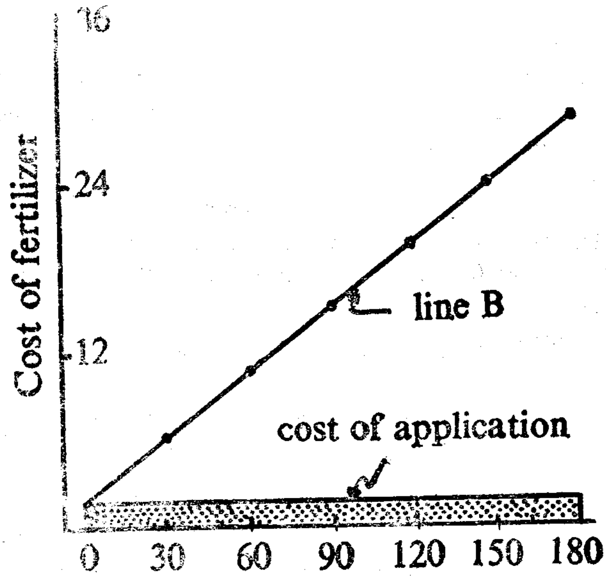
Many factors affect the growth and yield of crops, and any uncontrollable factor introduces an element of risk on money invested in fertilizer use. Some of these are :-

(a) Inadequate water for plant growth.
(b) Excess water (as in many parts of the wet zone).
(c) Insects.
(d) Plant diseases.
(e) Weeds.

Tying fertilizer use to the yield potential is one of the keys to profitable fertilizer use. Fertilizer use has to be balanced with yield potential for maximum profits. For example, increasing fertility rates without developing an insect control programme in a crop like rice can result in greater risk than if low levels of fertilizer are used.

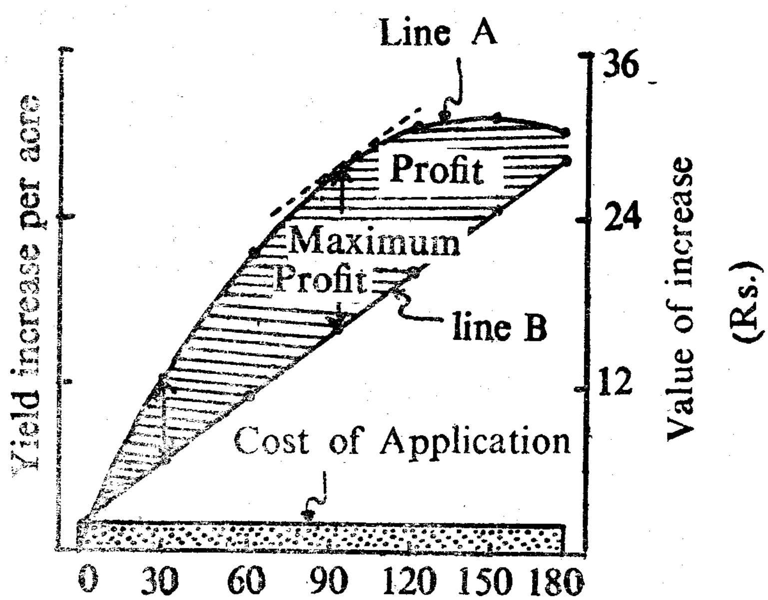


(a)



(b)

Rate of Nitrogen (lb/acre)



(c)

Rate of Nitrogen (lb/acre)

Chapter 10

THE CEYLON FERTILIZER CORPORATION

The Ceylon Fertilizer Corporation was established in January 1964 by order under the State Industrial Corporations Act: No: 49 of 1957. Its main function was to supply fertilizers for rice and tea (small holders) under the Government Subsidy Schemes in operation at that time and to import, store, distribute and sell fertilizers. It functions under the Ministry of Agriculture (Nandadeva, 1970). The total sales of fertilizer during the first six months of its existence has been reported to be more than 24,000 tons, almost 93 per cent of which was utilized for rice.

Under the Subsidy Scheme fertilizers for rice were sold exclusively through the Department of Agrarian Services, while other sales were usually direct or through the co-operatives to permit holders. The Corporation in addition, supplied fertilizers *ex-wharf* to private dealers.

Fertilizer formulations blended according to recommendations of various Research Institutes were also made available by the Corporation. These included mixtures for rice, tea, rubber and coconut. In addition, the Corporation carried stocks of various fertilizers to ensure no shortage of this important agricultural input before or during the season, especially for short term crops like rice.

Storage has been a problem. In 1968 fertilizer was imported in excess of space available for storage, with the result fertilizers had to be stored in the open at Hunupitiya (Nandadeva, 1970). This was with dire consequences.

Another vital drawback was that fertilizers were sometimes not available to farmers when needed. This was especially so in the remote areas. In an attempt to rectify this problem and to facilitate storage and distribution the Corporation initiated a scheme for decentralization of its stores and mixing plants.

Recently a master plan on the Sri Lanka - West German Fertilizer Project is reported to have been approved by the Cabinet, and a Fertilizer Secretariat has been established in the Ministry of Plan Implementation. The Major proposals envisaged include modernization of the port for handling fertilizer; establishment of five regional warehouses in Maho Trincomalee, Anuradhapura, Galle and Badulla; improvement of fertilizer mixing plants, and the provision of rail and road transport, equipment for fertilizer distribution along with the setting up of a transport repairs pool.

Another aspect is the provision of fertilizer aid to food crop and plantation sectors, credit facilities for fertilizer retailers and users with provision for re-financing (SUN, 1978).

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Chapter 11

DEFINITIONS

It is necessary to be familiar with the various terms used in the use of fertilizers. Examples are cited wherever possible to help clarify the definitions used:

Amount:

The quantity of fertilizers used. This may be expressed in pounds of mixed fertilizer (Example - 2,000 pounds of 6-8-8 per acre) or in pounds of actual plant food elements (Example - 120 pounds of nitrogen (N), 160 pounds of phosphoric acid (P_2O_5) and 160 pounds of potash (K_2O) per acre). Briefly, this can be written 120-160-160 pounds of plant nutrients per acre.

Grade:

Percentages of total nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O). (Example : a common grade is 6-8-8).

Ratio:

The relative proportions of N, P, and K contained in a fertilizer. This is obtained by dividing all percentage figures through by the lowest (fractions are not considered).

Source:

Refers to kind of materials or ingredients that are used to make the fertilizer. (Example - sources of nitrogen are ammonium nitrate urea, castor *poonac,* ammonium sulphate, etc.)

Simple or Straight: Materials consisting of simple chemical compounds of nitrogen, phosphorus and potassium.

Mixed fertilizers: A blend or mixture of two or more simples.

Complete fertilizer: Mixed fertilizers containing nitrogen, phosphorus, and potassium.

Placement:

Location and depth of the fertilizer in the soil in relation to the seed or plant. Fertilizers may be applied in two ways.

1. Broadcast - distributed evenly over the soil surface and where possible, mixed with the soil.

2. Banded - placed in a narrow strip or strips alongside the plants or seed, on or below the soil surface.

Timing:

Application of fertilizer at various intervals as determined by the need of the crop under various conditions. (Example - the initial or basic amount of fertilizer may be applied before planting, during planting, shortly after planting, or in split applications combining any two or all three of these) In addition, more fertilizer may be supplied later at intervals of time by side dress application.

Basic Fertilizer Application:

The primary or initial amount of fertilizer (other than supplemental) which is usually applied before, during, or shortly after planting, and which under normal conditions supplies the major fertilizer requirements of the crop.

Supplemental Fertilizer Application:

Additional fertilizer (over and above the basic amount) applied anytime during the growing season of the crop.

Side dressing:

The addition of fertilizer, either basic or supplemental, to a crop after it is planted.

APPENDIX

Table 1

CONVERSION OF WEIGHTS AND MEASURES

1 kilogram	—	2.20462 pounds
1 pound	—	0.45359 kilogram
1 hundredweight (cwt)	—	50.8023 kilograms
1 long ton	—	1.01605 metric tons
1 short ton	—	0.90718 metric tons
1 hectare	—	2.47109 acres
1 acre (4,840 square yards)	—	0.404687 hectare
1 bushel	—	20.865 kg = 46 lb.

Multiply by

lb/acre	1.121	kg/ha
cwt/acre	125.54	kg/ha
acres	0.405	hectares (ha)
square feet	0.093	sq. metres
square miles	2.590	sq. kilometres
kg/ha	0.892	lb/ac
kg/ha	0.008	cwt/ac

Table 2

Conversion table of lb/Kg N into lb/Kg of ammonium sulphate and urea.

lb/Kg	Ammonium Sulphate 21% lb/Kg	Urea 45-46% lb/Kg
10	48	22
20	95	44
30	143	67
40	190	89
50	238	111
60	286	133
70	334	155
80	380	178
90	428	200
100	476	222
110	524	244
120	571	266
130	619	289
140	666	311
150	714	333
160	762	355
170	810	377
180	856	400
190	904	422
200	950	444

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