Principles of Plant Nutrition and Fertilizer Use*

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NUTRIENT ELEMENTS

PLANTS require a number of chemical elements for their growth and sustenance. Thus far the elements considered essential for plant growth are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur which are called the major or macro-elements because they are required in relatively large amounts; and iron, copper, zinc, manganese, molybdenum and boron (possibly also chlorine) which are needed in relatively small quantities and are therefore referred to as the minor, micro-or trace elements. Of these elements, most of the carbon and oxygen are assimilated from the carbon dioxide of the air while hydrogen and oxygen are derived from water which is absorbed mainly from the soil, though to some extent also from the atmosphere. The other nutrient elements are absorbed almost exclusively from the soil.

ROLE OF ELEMENTS IN PLANT NUTRITION

Plant roots extract the nutrient elements present in the soil mostly in ionic form. These nutrient ions are then metabolised within the plant. A number of factors affecting the soil as well as the plant are concerned in nutrient ion absorption. When plants are unable to obtain adequate amounts of these nutrient ions, they suffer from deficiency diseases which result in poor crop growth, reduced yields and in extreme cases, even death of the plant. Deficiency diseases are usually marked by characteristic symptoms.

Nitrogen deficiency, for example, is characterised by the uniformly pale-yellow colour of the foliage and small stunted plants. Phosphorus deficient plants have a poorly developed root system, the leaves and stems are often small and have a greenish-red, reddish-brown, purple or bronze-like colour. Flowering and ripening are retarded and the fruit and seeds remain small. Potassium deficiency is first revealed by a yellowing of the tips and margins of the older leaves. These yellowing symptoms later extend towards the leaf bases and to the younger leaves. These yellowed areas become necrotic and die off, or appear reddish-brown or brownish-grey in colour.

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Deficiency symptoms appear because some essential metabolic process within the plant has been disturbed by the insufficiency of the element concerned. For example, nitrogen is essential for chlorophyll formation, phosphoric acid is an essential component in many enzyme systems and potassium regulates several metabolic reactions.

USE OF FERTILIZERS

Under natural conditions, the nutrient elements are continuously circulated between the soil and the vegetation and an equilibrium is eventually reached. Agricultural operations necessarily disturb this equilibrium. The crops grown are often not those found naturally in that particular environment and the harvested portions are removed for consumption in distant areas. The total quantity of nutrients present in the soil may then be inadequate to meet the needs of the growing crop. Fertilizers and manures are used to replenish the plant nutrients in the soil.

The nutrient elements may be present in the soil in forms that are not easily available to plants. An unfavourable soil reaction may be one of the causes. A suitable soil amendment will induce a more favourable soil reaction and hence an increased availability of the element concerned.

FERTILIZER MATERIALS

Fertilizers are generally inorganic in nature and are either manufactured or processed from naturally occurring substances. Substances like urea and cyanamide, which belong to the category of fertilizers, are really organic chemicals, Manures are invariably organic substances and are, perhaps for this reason, referred to as the " natural organics ". But just as fertilizers include organic substances like urea there is nothing " unnatural " about fertilizers when we consider the fact that sodium nitrate, as Chile saltpetre, or muriate of potash are present in naturally occurring deposits in different parts of the world.

The main fertilizers are those which supply the elements N, P and K. Calcium and magnesium are present in liming materials Sulphur is an ingredient in a number of NPK fertilizers. The trace elements can be added to fertilizer mixtures whenever necessary.

NOMENCLATURE

The plant nutrient content of fertilizers is still expressed in a terminology which is rather confusing. Nitrogen is referred to as the element, N ; phosphorus is expressed as " phosphoric acid ", P_2O_5 ; and potassium as " potash ", K_2O.

It will be clearly understood, of course, that elemental nitrogen is a gas and phosphorus pentoxide and potassium oxide are both reactive solids never found in fertilizer materials.

The formula expressing the *grade* of the fertilizer material indicates the amount of nitrogen, expressed as per cent. N, phosphorus expressed as the total, water-soluble or citrate-soluble P_2O_5, and potassium expressed as the water-soluble K_2O present. For example, a grade of 5–10–5 would mean that the fertilizer material has 5% of N, 10% of " available ' P_2O_5 and 5% of water-soluble K_2O. The grade formula reduced to simple terms is referred to as the ratio e.g., a 5–10–5 grade will have the same ratio, 1 : 2 : 1, as a 4–8–4 grade.

FERTILIZER COST

The prices of the different forms of fertilizing material are usually compared by the unit system. One unit is equal to one per cent. of a ton of the active constituent. Unit cost is found by dividing the price per ton of the fertilizer by the percentage of the constituent in question. For example, the unit cost of ammonium sulphate (21%N, Rs. 330 per ton) is 15.7, and the unit cost of urea (46% N, Rs. 580 per ton) is 12.6.

SOME COMMON FERTILIZER MATERIALS USED IN CEYLON

The main fertilizers used in Ceylon (Table 1) are ammonium sulphate, saphos phosphate, superphosphate, and muriate of potash which together constituted 94.4% of Ceylon's fertilizer imports in 1962. Urea and the ammonium phosphates are being increasingly recommended for rice while sodium nitrate is used whenever a quick response is desired. Potassium sulphate, though more expensive than muriate of potash, is used when the chloride ion is deleterious, e.g., on tobacco.

An important question to which no categorical answer has yet been forthcoming is the extent to which urea can replace ammonium sulphate in fertilizing the crops grown in Ceylon. In the proposed nitrogenous fertilizer factory, it is possible to manufacture either ammonium sulphate alone or both together in a suitable ration. The production of ammonium sulphate, however, involves the import of an additional raw material, sulphur, of which about 40,000 tons per year would be needed at a cost of Rs. 6 million in foreign exchange.

FERTILIZER APPLICATION

The amount of fertilizer to be applied to any particular crop and the rate and time of application will depend on a number of factors concerning the soil, the plant, the climate and cultural practices employed as well as economic considerations.

The original nutrient level in the soil, the extent of the availability of these nutrients, and the organic matter content are important considerations. The availability and the absorption of many plant nutrients, particularly phosphorus and the trace elements, will depend to a large extent on the pH of the soil. The pH range between 6.0 and 7.0 is the most favourable for the availability and effectiveness of most nutrients.

An initial basis for determining nutrient requirements is given by the nutrient removal as calculated from the yield and the nutrient content (Table 2). The nutrient removal is not, however, equal to the nutrient requirement. Added fertilizers are not completely utilized and may be leached away, fixed or volatilized. Legumes which show a large removal of nitrogen can extract much of this nitrogen from the air with the help of the symbiotic bacteria.

It is necessary also to know the period of growth during which a definite quantity of nutrients is required. Physiological studies on the growth habits of plants can provide this information.

Variety-fertilizer interaction is an important factor. Strong stem varieties of rice can be more heavily fertilized without the risk of lodging.

Climatic factors like rainfall, temperature, and light intensity, influence plant growth to a marked extent and fertilizer application will depend to some extent on these factors.

Cultural practices like disease and weed control, plant spacing, and the use of rotations will affect the pattern of fertilizer use.

LEVEL OF FERTILIZER DRESSING

Since one of the objectives of applying fertilizers is to increase crop yields, it is important to know the maximum crop yields possible with the application of fertilizer to a given crop. Fertilizer response curves (See Figure 1) indicate the variation in yield with increasing additions of fertilizer. The level of optimum fertilizer dressing will depend on the relationship between fertilizer cost and the prices realized for the agricultural product. The optimum dressing will be that quantity of fertilizer beyond which any further yield increase will be produced at a cost higher than the amount realised by the sale of the increased product. This is indicated in Figure 2.

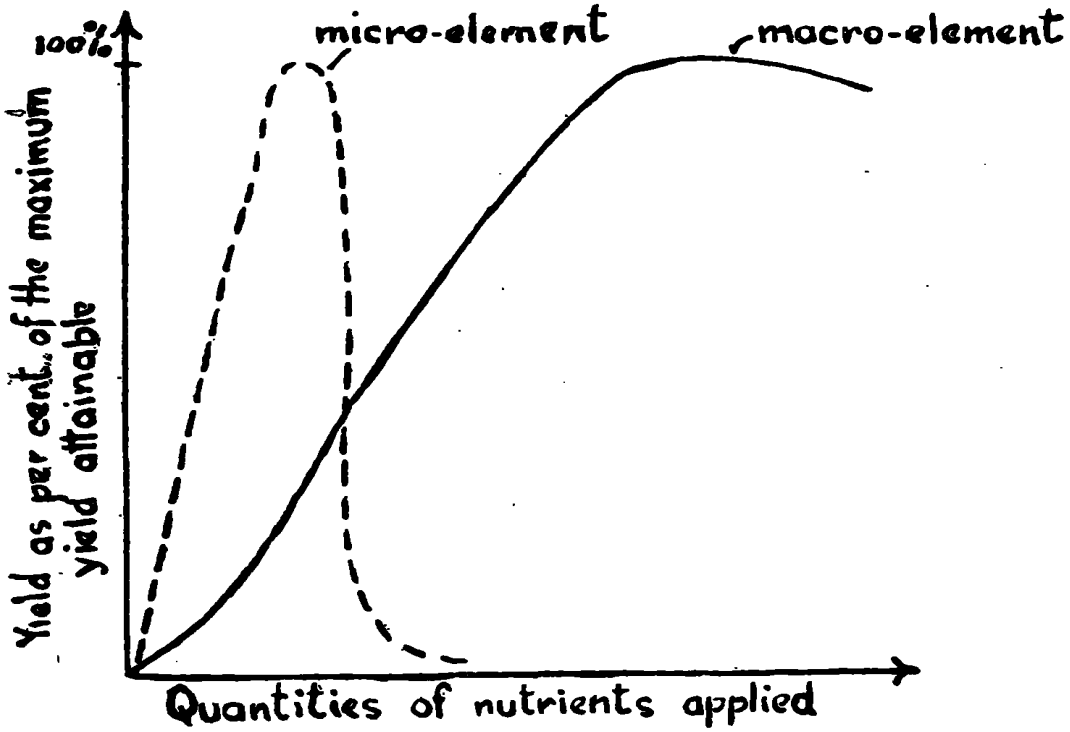
100%
micro-element
macro-element
Yield as per cent. of the maximum yield attainable
Quantities of nutrients applied

Fig. 1.

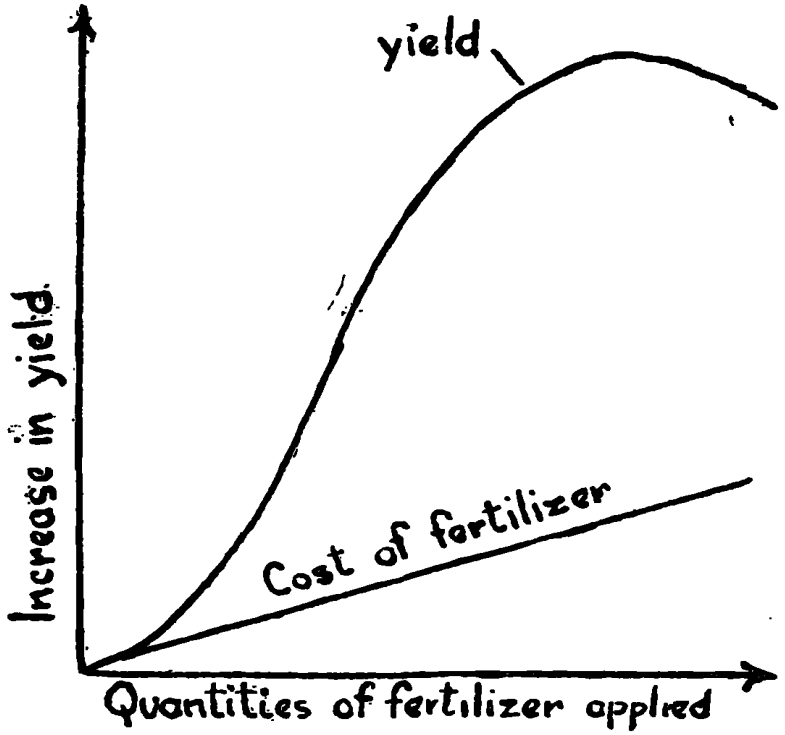
yield
Increase in yield
Cost of fertilizer
Quantities of fertilizer applied

Fig. 2.

TIME AND METHOD OF FERTILIZER APPLICATION

It is particularly important to supply nutrients at the proper time in the case of soils with a low nutrient content and with crops whose nutrient requirements are restricted to definite periods of time. It is impossible to lay down general rules since the individual nutrients fulfil different functions in the plant and are not required at the same instant. They also have different mobilities in the soil. Nitrogen is applied mainly as a top dressing at the time of vegetative growth, phosphorus as a basal application, and potassium both as basal and as a top-dressing.

There are three distinct methods of fertilizer application : broadcasting, placement and spraying. These are designed to make maximum use of the fertilizer applied. Broadcasting is practised on all crops with a dense stand and for plants whose roots permeate the whole soil volume. Placement is used in the distribution of small amounts of fertilizer, wherever there is a danger of fixation in the soil and on plants with a poorly developed root system spaced far apart. Wherever nutrients tend to get fixed in unavailable forms, and particularly with certain trace elements, spraying is the most effective method of application.

TABLE I—Some fertilizer materials used in Ceylon

Fertilizer	Average Composition per cent.			Approx. Cost per ton Rs.	Unit Cost Rs.
	N	P_2O_5	K_2O		
Sulphate of ammonia ..	21	—	—	330	15·7
Chile saltpetre ..	16	—	—	520	32·5
Urea ..	46	—	—	580	12·6
Calcium cyanamide ..	20·6	—	—	590	28·6
Ammonium nitrate ..	35	—	—	650	18·6
Ammonium phosphate ..	16	20	—	595	16·5
Superphosphate ..	—	18	—	310	17·2
Conc. superphosphate ..	—	42	—	525	12·5
Saphos phosphate ..	—	29·5	—	260	8·8
Sulphate of potash ..	—	—	48	510	10·6
Muriate of potash 50 per cent ..	—	—	50	385	7·7
Muriate of potash 60 per cent ..	—	—	60	425	7·1
Bone meal ..	3	22	—	400	16·0
Crushed fish ..	4	4	—	305	38·2
Fish guano ..	7	6	—	420	32·4
Animal meal ..	7	10	5	500	22·8
Blood meal ..	11	—	—	720	65·5
Farm yard manure ..	0·4	0·3	—	—	—
Compost ..	0·5	0·25	0·5	—	—

TABLE II—Nutrients removed by various crops

(from Fertilizer Use by A. Jacob and H. V. UexKull)

Crop	Yield per acre	Nitrogen N lb./acre	Phosphorus P_2O_5 lb./acre	Potassium K_2O lb./acre
Rice ..	35 cwt. grain 24 cwt. straw	58	18	67
Tea ..	400 lb. manufactured tea	31	4	13
Coconut ..	50 palms	66	28	123
Rubber ..	350 lb. latex	42	5	19
Sugar cane ..	36 tons cane	76	54	170
Cotton ..	350 lb. lint 800 lb. seed	75	30	78
Pineapples ..	16 tons	98	27	245
Tobacco ..	16 cwt.	116	36	214