Jl. Rubber. Res. Inst. Sri Lanka (1981) 59, *13—19*

UREA AS A SOURCE OF NITROGEN FOR RUBBER PLANTATIONS IN SRI LANKA. I. A REVIEW AND PRELIMINARY OBSERVATIONS

By

N. YOGARATNAM

SUMMARY

Urea fertilization is a new subject to rubber growers in Sri Lanka . This paper is therefore published in the hope that it would serve to acquaint the fertilizer users with this subject particularly with regard to its benefits and limitations. Examples have been drawn from published work in other countries and unpublisehed preliminary observations made in Sri Lanka. Part II of this series deals with detailed agronomic investigations carried out in Sri Lanka.

Fertilizer input constitutes an important investment in rubber production. Even though urea has consistently been the cheapest nitrogenous fertilizer available in the market, it has not been used to any significant extent by the plantation industry, in particular the rubber industry. Interest in its use was however given an impetus by the decision of the government to set up a plant to manufacture urea in Sri Lanka.

The use of urea as a synthetic nitorgen fertilizer began when a cheap industrial process became available in the 1920s for its preparation from Calcium Cyanamide (CaN.CN).

$$CaN.CN + 3H_20 \longrightarrow H_2N.CO.NH_2 + Ca(OH)_2$$

The most common method currently employed in the preparation of urea is by using liquid ammonia and carbondioxide;

$$2NH_3 + CO_2 + H_20 \longrightarrow (NH_4)_2\ CO_3 \longrightarrow NH_2.CO.NH_2 + 2H_20$$

This reaction which requires high temperatures and pressures produces ammonium carbonate $(NH_4)_2\ CO_3$ as an intermediate which is dehydrated to give urea. The urea solution obtained is then used for producing solid urea. Two major drawbacks in the use of this synthetic crystalline urea as a fertilizer were its hygroscopicity and presence of biuret in toxic levels. Because of high hygroscopicity crystalline urea, either straight or in mixtures with other fertilizer components, would become moist, cake on storage and have poor handling properties. This disadvantage has been overcome to a large extent by the production of prilled (pelleted) urea which has better storage and handling properties, and by packing it in moisture-proof bags. Urea with even better physical properties is now being prepared by coating the prills with inert substances, like resin or elemental sulphur (Army 1963; Terman and Hunt 1964). The storage properties of urea in fertilizer mixtures were improved further by substituting other nutrients *e.g.* commercial Epsom Salts ($MgS0_4.7H_20$) which were used as the source of magnesium in rubber fertilizer mixtures, with Kieserite ($MgS0_4.H_20$) or Dolomite ($CaC0_3.\ MgCO_3$) as recommended by the Rubber Research Institute of Sri Lanka 1980.

During the manufacture of urea, the high temperature used may cause the condensation of two molecules with the elimination of ammonia to give biuret ($NH_2.CO.NH$ $CO.NH_2$) as an impurity in the final product.

$$2NH_2.CO.NH_2 \longrightarrow NH_2.CO.NH.CO.NH_2 + NH_3$$

The high amounts of biuret in the early urea preparations were found to be phytotoxic because plants are unable to metabolize biuret and tend to accumulate it (Impey and Jones 1960). Recently new technological processes have been developed to produce urea of low biuret content. The urea manufactured in Sri Lanka contains less than 1% biuret and can therefore be used safely on a variety of crops, even as a foliar spray (Yogaratnam 1975).

Advantages of urea

Urea is the cheapest source of nitrogen fertilizer presently available for use in rubber plantations. This is due in part to the fact that sulphuric acid, which is expensive, is not used for urea manufacture but is obviously required for the manufacture of ammonium sulphate. Because urea has a high nitrogen content (46% N) transport and handling charges and possibly even application costs are low.

Urea has yet another advantage in that it does not acidify the soil to the same degree as some of the non-calcium containing nitrogenous fertilizers such as ammonium sulphate. It has been reported that 8·2 kg of calcium carbonate is required to neutralize the acidity caused by 4·5 kg nitrogen as urea, whereas 24.5 kg calcium carbonate is required to neutralize the acidity caused by 4.5 kg nitrogen as ammonium sulphate. Hence in rubber plantations where sulphate of ammonia has been used continuously as the only source of nitrogen and in soils where acidity is a problem, the use of urea is definitely advantageous.

Limitations for urea as fertilizer

Hydrolysis of urea: Although small amounts of urea applied to the soil may be taken up directly by the plant (Webster, 1959), the major portion is first converted to inorganic nitrogen (ammonium) before absorption. Gibson (1930) suggested that the conversion of organic urea to inorganic ammonium carbonate in the soil was a biological process initiated by microorganisms which contained the enzyme urease; but, Conrad (1940) showed that the hydrolysis of urea in the soil was to a great extent due to thermolabile catalytic activity, in addition to the microbial action of microorganisms.

$$H_2N.CO.NH_2 + H_20 \longrightarrow (NH_4)_2CO_3$$

The rate and extent of hydrolysis of urea in the soil therefore depends on the microbial activity of the soil, which in turn depends on factors such as fertility, soil teperature, soil pH (Martin and Chapman 1951), and soil moisture content.

Silva and Perera (1971) studying the urease activity in the rubber soils of Sri Lanka, observed that the levels of urease activity in these soils are satisfactory for the use of urea as a fertilizer.

Volatilisation losses of nitrogen: The production of ammonium carbonate on hydrolysis causes a temporary increase in soil pH. An increase in pH, particularly if it exceeds seven which is very unlikely in rubber-growing soils of Sri Lanka with their pH range of 4.5 to 5 may cause the release of one molecule of ammonia from ammonium carbonate with the formation of the more stable ammonium bicarbonate.

$$(NH_4)_2\ CO_3 \longrightarrow NH_4HCO_3 + NH_3$$

The release of ammonia by hydrolysis has two disadvantages. Firstly it can cause injury to germinating seeds and to emerging young plants. This problem has been overcome by separating the urea and seed by soil at planting (Widdowson and Penny 1963), or by mixing urea with acid material such as superphosphate before applying to the soil (Low and Piper 1961). In rubber plantations in which the present practice is to use budded stumps or polybag plants (Samaranayake 1980), this problem does not arise. Yogaratnam (1980) found that urea was as good as ammonium sulphate for application to young plants both in the field nursery and in 'polybags'.

It should be possible to prevent or at least reduce the losses of ammonia by volatilisation by incorporating the urea into the top 1 inch of the soil, by forking or by placing it below the surface. The same result can also be obtained if the broadcast urea, is soon washed into the soil by rain, for once the urea is below the surface any ammonia released by hydrolysis would be absorbed and retained in the soil. The ability of a soil to absorb ammonium ions is determined by its cation exchange capacity (CEC). Thus losses would be greater from soils with a low CEC, particularly sandy soils as compared to rich organic soils which have higher CEC (Gasser 1964). Decomposition of urea and losses of ammonia by volatilisation are dependent on the soil moisture content and the presence of leaf litter. Work done in Malaysia showed that when urea was applied on the surface of moist loam or sandy loam soils, losses of upto 24% were observed. However, when this fertilizer was applied to the bare surface of clay soils, *e.g.* Selangor series, little or no loss was observed. Even with loam and sandy loam soils saturated with moisture, the loss of urea did not exceed 10%. When urea was applied on leaf litter under mature rubber trees a loss of 10-18% was recorded, such losses being observed irrespective of the soil type (Rubber Research Institute of Malaysia, 1961).

Nitrification of urea nitrogen: Nitrification is the microbiological process in the soil whereby ammonium ions are oxidized to nitrate ions. This process occurs in two stages; firstly ammonium is oxidized to nitrate by *Nitrosomonas* bacteria, followed by oxidation of nitrite to nitrate by *Nitrobacter* bacteria.

$$2NH^+_4 + 3O_2 \xrightarrow{\textit{Nitrosomonas}} 2NO^-_2 + 2H_2O$$

$$2NO_2 + O_2 \xrightarrow{\textit{Nitrobacter}} 2NO_3$$

Both these bacteria function well in soils with a nearly neutral or slightly alkaline pH 6.8-8.0, and the lower limit for their activity in the soil is around pH 4.0 (Waksman 1927). Normally the *Nitrobacter* is more active and therefore nitrite is oxidized to nitrate as fast it is formed. If the soil pH is high (8.5) then *Nitrosomonas* activity resulting is also high in the accumulation of nitrite (Campbell and Lees 1967). Nitrite is not assimilated by plants and is considered phytotoxic if found in excess (Court *et al* 1962).

It is well known that the content of NO_3-N and NH_4-N in soil varies widely with climatic conditions, uptake by plants and bilogical activity, particularly nitrification in the soil. In soils with active nitrification the ratio between N-NO_3 and N-NH_4 should be at least 1 : 1. It seems, from a study by Yogaratnam and Silva (1978), that only in some of the rubber-growing soils in Sri Lanka (*e.g.* some of the *Parambe* soils) is nitrification less favourable. Nevertheless, when urea is applied to rubber soils, which are usually acidic, the initial hydrolysis of ammonium carbonate results in an increase in pH. This pH rise even though transistory, favours the activity of nitrifying bacteria and increases nitrification. Values exceeding pH 8.0 have not been observed in the rubber growing soils in Sri Lanka (Yogara ratnam and Silva 1978), therefore nitrite accumulation is unlikely to occur.

Soil application of urea

Ammonium fertilizers such as ammonium sulphate when applied to the soil ionize in the presence of moisture to give positively charged ammonium ions (NH^+_4). These ions are then held rather firmly by the strong cation exchange sites present on soil colloids. In contrast, the negatively charged nitrate (NO^-_3) anions, formed either by ionization of nitrate salt applied to the soil (which is not a common practice in rubber plantations in Sri Lanka) or by nitrification of ammonium ions, are only held feebly because the anion-exchange complexes of soils are relatively weak. As a consequence percolating rain water readily leaches out the weakly-held nitrate and nitriate anions, but the strongly held ammonium cation is not easily removed.

Urea does not dissociate into charged ions in solution as it is a non-electrolyte. In theory then it should not be held by either of the ion-exchange complexes of the soil and as a result should be leached readily into the deeper layers of soil. But Broadbent *et al* (1958) and Bhavanandan (1969) showed that urea is not so easily leached and that it moves less rapidly than nitrate in soil. One reason for this unexpected result with urea may be its rapid conversion to ammonium carbonate and the subsequent retention of ammonium. Alternatively it has been suggested by Chin and Kroontje (1962) that urea forms an addition complex with organic matter of the soil and is therefore not easily leached out while Broadbent *et al* (1964) favour salt formation between the weakly basic urea and the weakly acidic groupings, like carboxyl , of the soil as being responsible for urea retention.

Urea has certain disadvantages compared with ammonium sulphate with regard to leachability. Under the rainfall conditions prevailing in most rubber-growing areas in Sri Lanka, the aim should be to incorporate the fertilizers into the soil rapidly in order to prevent loss by surface wash and volatilisation and this is normally achieved by pocketing or forking. However, under these conditions it is possible that at least part of the urea may be leached into deeper layers of soil below the root zone. This loss can be avoided by only placing the fertilizer just below the soil surface at depths of approximately 6 to 12 cms depending on the age of the plants.

Foliar spraying of urea

Supplementing the nitrogen nutrition of field and plantation crops by foliar spraying with urea has become an accepted practice (Finney *et al* 1957, Labanauskas *et al* 1962). Moreover, as urea is highly soluble in water and is less corrosive than other fertilizer salts, is also well suited for soil application, either by injection or by addition to irrigation water. Urea is compatible with most insecticides and fungicides and also with other fertilizers such zinc sulphate, Epsom Salts and borax (Yogaratnam 1975) for foliar spraying.

Yogaratnam and Greenham (1982), studying the effects of foliar sprays of urea on fruit set of apple observed an increase in fruit set in trees that were not deficient in nitrogen and therefore recommended that apple orchards should be sprayed routinely with urea.

Bhavanandan (1969) working on tea, noticed very little or no damage with urea concentrations up to 3% when sprayed at the rate of 100 gallons per acre.

On rubber preliminary observations made by Yogaratnam and Karunaratne (1976) indicated that urea foliar sprays could be used successfully in the field nursery and on young immature plants. However, as the annual nitrogen requirement of rubber plants in the first and second years of planting is approximately 7 kg and 15 kg , respectively, foliar spraying with urea may not have a significant economic effect.

Agronomic investigations

Several experiments have been carried out to test the efficiency of urea as a fertilizer but the results are variable. In tea, experiments carried out from 1958 to 1961 at the Japanese Tea Experimental Station showed that urea was as good as and, in some instances, better than ammonium sulphate. In East Africa results of an experiment at Kericho demonstrated that urea was less effective per unit of nitrogen than ammonium sulphate but in contrast it was reported from the Kyawage district in Uganda that urea and ammonium sulphate gave the same response (Wilson 1967). In Sri Lanka, Bhavanandan and Sunderalingam (1971) tested ammonium sulphate, urea and calcium ammonium nitrate at two levels of nitrogen but found no significant difference in yield between the three fertilizers during the first 7 years of the experiment.

Urea has been reported to be less effective than ammonium sulphate as a fertilizer for oil palm in Malaysia. Foster (1975) observed that at the same nutrient levels, ammonium sulphate increased oil palm yields by 47% compared with 14% for urea. In another trial sulphate of ammonia and Nitro-26 gave higher yields than urea when nitrogen was applied at the rate of 0·5 kg per palm per year (Ng. 1976).

In Malaysia it has also been reported that urea was less effective than ammonim sulphate as a fertilizer for rubber. Sivanadyan (1972) and Soong (1973) have shown that urea gave the poorest increase in dry matter when applied to soils of the Serdang and Mienchang series (Sandy Loam and Clay Loam, respectively). But on coastal soils, Pushparajah (1964) found that urea and ammonium sulphate were equally effective. In another report (Anon 1976) it has been claimed that in order to get the same yield of rubber twice as N had to be used when the source was urea as with ammonium sulphate.

Some of the possible reason for these variable and contradictory results have been investigated and the results reported in the following paper (Part II).

REFERENCES

ANON. (1960. A pocket book of agricultural tables. Shell International Chemical Company Limited, London, 192 pp.

ANON. (1976). *Rep. Rubb. Res. Inst. Malay,* 1976, 120-121.

ARMY, T. J. (1963). Coated fertilizers for the controlled release of plant nutrients. *Agric. Chemicals* **18**, 8, 26.

BHAVANANDAN, V. P. (1699). Report of the Agricultural Chemistry Division. *Rep. Tea Res. Inst. Ceylon* (1968), **2**, 18-38.

BHAVANANDAN, V.P. & SUNDARALINGAM, S. (1971). The effect of nitrogen fertilizers on soil acidity, soil urease activity and leaf nutrient content on yield of tea. *Tea Inst.* **42**, 40-47.

BROADBENT, F. E., HILL, G. N. & TYLER, K. B. (1964). Salt formation as a basis of urea retnetion in soils. *Soil Sci. Soc. Amer. Proc.* **28**, 292-294.

CAMPBELL, N. E. R. & LEES, H. (1967). The nitrogen cycle in soil biochemistry. Edited by McLaren and Peterson. Edward Arnold Ltd., London, 509 pp.

CHIN, WET-TSUNG. & KROONTJE, W. (1962). Mechanism of urea absorption by soils. *Soil Sci.* **26**, 479-481.

CONRAD, J. P. (1940). The nature of the catalyst causing the hydrolysis of urea in soils. *Soil Sci.* **50**, 119-134.

COURT, M., STEPHEN, R. C. & WAID, J. S. (1962). Nitrite toxicity arising from the use of urea as a fertilizer. *Nature.* **194**, 1263-1265.

FINNEY, K. F., MAYER, J. W., SMITH, F. E. & FRYER, H.C. (1957). Effect of foliar spraying Pawnee wheat with urea solutions on yield, protein content and protein quality. *Agron. J.* **49**, 341-347.

FOSTER, H. C. (1975). Comparision of different fertilizer nutrient sources for oilpalm-a *review*.

GASSER, J. K. R. (1964). Urea as a fertilizer. *Soils & Fert.* **27**, 175-180.

GIBSON, T. (1930). The decomposition of urea in soils *J. Agric Sci.* **20**, 549-558.

IMPEY, R. L. & JONES, W. W. (1960). Effect of biuret on nitrogen status of Washington navel and Valencia orange leaves. *Proc. Amer. Soc. Hort. Sci.* **76**, 186-192.

LABANAUSKAS, C. K., JONES, W. W. & EMBLETION, T. W. (1962). Effects of foliar applications of manganese, zinc and urea on yield and fruit quality of Valencia oranges and nutrient concentration in the leaves, peel and juice. *Proc. Amer. Soc. Hort. Sci.* **82**, 142-153.

LOW, A. J. & PIPER, F. J. (1961). Urea as a fertilizer. Laboratory and pot-culture studies. *J. Agric. Sci.* **57**, 249.

MARTIN, J. P. & CHAPMAN, H. D. (1951). Volatilization of ammonia from surface fertilized soils. *Soils Sci.* **71**, 25-34.

NG, S. K. (1976). Review of oilpalm manuring. Scope for greater economy in fertilizer usage. *Malaysia International Agricultural Oilpalm Conf. Kuala Lumpur*, 1976, 209-233.

PUSHPARAJAH, E. (1964). Data from three field experiments comparing mixed fertilizers with granualted compound fertilizers. *Res. Arckc. Rubb. Res. Inst. Malaysia, Docum.* 36.

Rubber Research Institute of Malaysia (1961). Loss of ammonia from surface applications of urea fertilizers. *Plns Bull. Rubb. Res. Inst, Malaya* (57), 180.

Rubber Research Institute of Sri Lanka (1980). Fertilizers to rubber, *Advisory circular No. 85.*

SAMARANAYAKE, C. (1980). Personal communications.

SILVA, C. G. & PERERA, A. M. A. (1971). A study of the urease activity in the rubber soils of Ceylon. *RRIC Quart. Jl,* 47, 1-2, pp 30-36.

SIVANANDYAN, K. (1972). Lysimeter studies on the efficiency of some potassium and nitrogenous fertilizers on two common soils in West Malaysia. *Proc. 2nd Asian Soil Conference Djakarta,* 1972.

SOONG, J. K. (1973). Effects of nitrogenous fertilizers on growth of rubber seedlings and leaching losses of nutrients. *J. Rubb. Res. Inst. Malaysia.* **23**, 356-364.

TERMAN, G. L. & HUNT, C. M. (1964). Volatilization losses of nitorgen from surface applied fertilizers, as measured by crop-response. *Soil Sci. Soc. Amer. Proc.* **28**, 667-672.

WAKSMAN, S. A. (1927). Principles of soil microbiology. Bailliers, London, 897 pp.

WEBSTER, G. C. (1959). Nitrogen metabolism in plants. Row, Peterson, and Company, White Plains, New York, pp. 152

WIDDOWSON, F. V. &. PENNY, A. (1963). Alternative nitrogen fertilizers for spring barley *Rep. Rothamst. Exp. sta.* 1962, 47.

WILSON, K. C. (1967). Forms of nitrogen. *Tea, E. Africa,* **8**, 11-20.

YOGARATNAM, N. (1975). Effects of nutrient sprays on fruit set, mineral composition and fruit quality of apple. PhD Thesis, University of London.

YOGARATNAM, N. (1980). Review of the Soils & Plant Nutrition Department for the year 1980. *Rubb. Res. Inst. Sri Lanka.* 69-82.

YOGARATNAM, N. & GREENHAM, D. W. P. (1982). The application of foliar sprays containing nitrogen, magnesium zinc and boron to apple trees. I. Effects on fruit set and cropping. *J. Hort. Sci.,* **57** (2) 1982.

YOGARATNAM, N. & KARUNARATNE, A. D. M. (1976). Unpublished data. *Rubb. Res. Inst. Sri Lanka.*

YOGARATNAM, N. & SILVA, F. P. W. (1978). Standardization of soil testing methods for the rubber soils of Sri Lanka. *Proceedings of the mineral session of the Sri Lanka Association for the Advancement of Science, December 1978.*