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UREA AS A NITROGEN FERTILIZER FOR RUBBER PLANTATIONS IN SRI LANKA. II AGRONOMIC INVESTIGATIONS

By

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SUMMARY

This paper presents the results of five experiments carried out to study the effectiveness of urea as a nitrogen fertilizer for rubber in Sri Lanka. Growth and yield data obtained from experiments varying in duration from 5 to 10 years have indicated that urea is as effective as ammonium sulphate if the fertilizer is placed below the soil surface by forking in. When broadcast, urea was significantly more volatile than ammonium sulphate but when forked into the soil there was little difference between these two fertilizers. Continuous application of ammonium sulphate increased the SO_4 content of the soil but decreased the soil pH. Application of urea increased the soil urease activity. It therefore appears that urea may be used as a source of nitrogen for rubber in Sri Lanka without any adverse effects on production.

The need for fertilizers for rubber is well known but full benefits can only be achieved if the fertilizers are applied efficiently. These advantages should be judged on the effective cost per unit of nutrient, the efficiency of uptake by the plant and the returns on the investment. Obviously the appropriate fertilizer at the correct rate must be applied by the most efficient method to suit a particular plant/soil environment and the resultant benefits must be of economic advantage to the grower.

The use of urea as a fertilizer for rubber is becoming increasingly important in view of its manufacture in Sri Lanka. The experiments reported in this paper were therefore designed primarily to determine the effectiveness of urea as a source of nitrogen for rubber in Sri Lanka.

MATERIALS & METHODS

Four field and one laboratory experiment, varying in duration from 10 days to 9 years were carried out in rubber plantations in Sri Lanka.

Experiment 1

This experiment was designed to compare the effects of three forms of nitrogen on growth and yield of rubber. The experimental trees were PB 86 planted in May/June 1976 at 6x3m and grown with a mixed leguminous cover of *Pueraria phaseoloides* and *Desmodium ovalifolium*.

The soil, classified as from the *Boralu* series (Silva 1964) is shallow, gravelly loam, brown to reddish yellow in colour and overlying cabook. It is characterised by the presence of iron concretions which occur throughout the soil mass. Routine soil analysis (Yogaratanam and Silva 1978) indicated the following mean values: pH-4.6; CEC-5.93; available phosphorus-2.17; potassium-0.04; and magnesium-0.04 mg/kg soil in the planting strips. The total N averaged 0.11% of air-dry top soil and the water holding capacity ranged from 40-60%.

The three forms of nitrogen tested in this experiment were ammonium sulphate, urea and ammonium chloride. The fertilizer treatments together with a control without N, were applied to experimental plots, each plot consisting of 30 to 40 measuring trees surrounded on all sides by one row of guard trees in a 4³ factorial design with single replication. Nitrogen was applied at the rates of 6.8, 13.6, 20.4 and 27.2 kg/ha in the years 1, 2, 3, 4 and 5 after planting. All plots received uniform applications of P, K and Mg according to the recommendations of the Rubber Research Institute of Sri Lanka (RRISL) and fertilizers were forked into the soil at a depth of 15 cm.

Experiment 2

This 9-year experiment was started in 1972 on mature PB 86 plants that were tapped on virgin bark. The soil characteristics were similar to that in Experiment 1 and were fairly uniform in all the experimental areas.

Four fertilizer treatments-control without nitrogen, ammonium sulphate forked in urea forked in and urea broadcast, were applied to plots each with 20-30 measuring trees in a randomized block on twelve sites in commercial plantations with two replications in each site. The plantations were at Sorana, Lowmont, Clyde, Pahan, Neuchatel, Nelunuyana, Paiyagala, Vogan, Maddeggedera, Kuruwita and Gikiyanakanda. Nitrogen was applied at a uniform rate of 20.5 kg/ha to all the plots except the control. All plots received uniform applications of P, K and Mg according to the recommendations of the RRISL.

Experiments 3 and 4

Two experiments were carried out in Dartonfield to determine the losses of ammonia by volatilization from urea and ammonium sulphate according to soil type, moisture content of the soil and methods of application in the field.

For the laboratory experiment (3) soil samples were collected from six soil series. Three locations were selected in each soil series and at each location 12 sites were sampled. From each site two samples were removed from a depth of 0-7.5 cm and about two feet apart. The water holding capacity (WHC) of the soils was adjusted to 0-5, 45-50 or 95-100%. The method of Volk (1959), as modified by Watson *et al.* (1962), was used to measure the loss of ammonia from the nitrogen fertilizers applied to the soil. Petri dishes with filter paper on the inner side of the glass lid were used for the measurements in the laboratory.

A field experiment (4) was carried out to test the effects of methods of application of nitrogen fertilizers on ammonia losses in Agalawatta series soil. This soil is variable in depth, often shallow, and frequently strewn with boulders and outcrops of the granitic rocks from which they are derived. They are silty clay loam and strong brown to reddish in colour. Four fertilizer treatments were applied to plots in a randomized block with four replications as follows: . .

ammonium sulphate—broadcast
 ammonium sulphate—forked in (15 cm)
 urea—broadcast
 urea—forked in (15 cm).

In this experiment bell jars were inverted over the area where the experimental fertilizers were applied. Cotton wool pads were placed on tripods inside the bell jars and the experiment continued for 15 days. The rest of the procedure was the same as that for Experiment 3.

Experiment 5

This forms part of a cooperative study between the Rubber Research Institute of Sri Lanka and the Royal Tropical Institute in the Netherlands. Soil samples were collected from five soil types from both the densely rooted top layer, which varies in thickness from 15 to 20 cm, and from the underlying layer of 10 cm thickness. Three locations were selected in each soil series and at each location 12 sites were sampled. The sulphate content of the soil was determined by extraction with ammonium acetate/acetic acid, pH 4.8, (soil/ extractant ratio 1:2.5, shaking time 30 minutes) and by flame emission spectroscopy.

RESULTS

Effect of different forms of nitrogen fertilizers on growth of immature rubber Experiment 1: The response in terms of growth to fertilizers applied during the immature period may be gauged from the yearly mean trunk girth increment commencing from about 18 to 24 months after planting up to the end of the immature period. For Experiment 1 the trunk girth was measured at a point 90 cms above the graft union in November/December each year. Analysis of covariance was performed in logarithmic transformations of the trunk girth increase in each year compared with the girth at the end of 18 months from planting, *i.e.* in November/December 1977. For convenience the untransformed values of yearly mean girth increments are presented in Table 1, but the significance of their differences from the controls (nil nitrogen) refers to the analysis of covariance on transformed values.

Table 1. *Effect of nitrogen fertilizers on growth of PB 86 (Experiment 1)*

Treatment	Trunk girth increment (cm)			
	1977-78	1978-79	1979-80	1980-81
Control (nil nitrogen)	0.249	0.316	0.329	0.341
Ammonium sulphate	0.275	0.372*	0.420*	0.334
Urea	0.280	0.390*	0.417*	0.341
Ammonium chloride	0.259	0.381*	0.389*	0.339

In all tables LSD is the least significant difference between (1) and any other treatment and *, **, ***, indicate those treatments differing from the control (1) at $P = 0.05$, 0.01 and 0.001 respectively.

All three sources of nitrogen tested, *viz.* ammonium sulphate, urea and ammonium chloride, have increased the girth of plants in comparison with the control treatment (nil nitrogen). These increases tended to be consistent and were significant at the end of 42 and 54 months from planting. But during the latter period of immaturity (end of 66 months) the response to nitrogen application declined and a negative trend was shown. In general the results indicate that there was no difference between ammonium sulphate, urea and ammonium chloride, in their effect on trunk girth increment during the immature period of the cycle.

Effect of nitrogen fertilizers on yield Experiment 2: The post-treatment mean yields of rubber obtained with applications of urea or ammonium sulphate over a 5-year period of Experiment 2 (from 1977 to 1981) are given in Table 2. Pre-treatment yields were recorded for 5 months, totalling eight recordings. Where post treatment yields were affected by pre-treatment differences, as revealed in covariance analysis, they were adusted accordingly.

It is clear that nitrogen fertilizers have consistently given higher yields in comparison with the trees that did not receive any nitrogen from 1972, this response was independent of the source of nitrogen applied. The difference in the yields, however, was not always statistically significant. On a percentage basis, nitrogen fertilizers gave a 12% increase in yields over the 5-year period, but had no effect on the girthing of the trees (results not presented).

Table 2. *Effect of nitrogen fertilizers on yield of PB 86 (Experiment 2)*

	Mean yield (kg/ha)					Total 1977 to 81	% Relative to control
	1977	1978	1979	1980	1981		
Control (Nil nitrogen)	2340	1861	1492	1666	1645	9004	100
Ammonium sulphate forked in	2494	2086*	1717*	1974*	1852	10123*	112
Urea-forked in	2463	2144*	1703*	2014*	1876	10200*	113
Urea-broadcast	2346	1969	1619	1976*	1702	9612*	106
LSD	212	189	131	203	239	406	4.51

A comparison between the different sources of nitrogen and methods of their application indicated that ammonium sulphate and urea forked in, have consistently given higher yields than urea applied by broadcasting, although the differences have not always been significant. Over the last 5 years of the experiment, urea forked in, gave 1196 kg more rubber than the nil nitrogen plots, which amounted to a 13% increase as compared to a 6% increase when urea was applied by broadcasting. Ammonium sulphate had also given 1119 kg more rubber than the control.

Effect of nitrogen fertilizers on leaf composition Experiments 1 and 2: Leaf samples were analysed to show the nutritional status of the trees and to provide an indication of nutrient uptake from the fertilizer treatments. Samples were collected in August/September each year according to standard programme adopted at the RRISL (Yogarathnam and Silva 1977). Nitrogen and P were measured colorimetrically, K and Ca by flame emission spectroscopy and Mg by atomic absorption spectroscopy.

The nitrogen content of the leaves is presented in Tables 3 and 4 and shows that leaf N had been influenced by the fertilizer treatments. In Experiments 1 and 2 the leaves from plants that received ammonium sulphate and urea by forking in, had a significantly higher leaf nitrogen content than the control treatment in both 1979 and 1980.

There were no relationships between the phosphorus, potassium, and calcium concentration in leaves and the types of nitrogen and the methods of application tested in this study.

Table 3. *Effect of nitrogen fertilisers on mean N content in leaves (Experiment 1)*

Treatments	Mean N content (%)		
	1978	1979	1980
Control	2.25	2.34	2.81
Ammonium sulphate	2.38	2.52	3.20*
Urea	2.45	2.56	3.21*
Ammonium chloride	2.38	2.49	3.18*
LSD (P=0.05)	0.26	0.31	0.29

Table 4. *Effect of nitrogen fertilizer on mean N content in leaves (Experiment 2)*

Treatments	Mean N content (%)			
	1977	1978	1979	1980
Control	2.92	3.18	2.74	2.71
Ammonium sulphate	2.81	3.34	2.94*	3.02*
Urea-forked in	2.99	3.37	3.04*	3.14*
Urea-broadcast	2.96	3.20	2.85	2.92
LSD (P=0.05)	0.34	0.22	0.18	0.24

Effect of nitrogen fertilizers on soil pH and SO₄ content Experiments 2 & 5: The influence of nitrogen fertilizers on soil pH was investigated by testing soil samples taken from the experimental plots (Experiment 2) in January 1972 and December 1981. Soil pH was determined using air dried soil in a 1:2.5 soil-water suspension. In general the pH of soil in the experimental plots has not shown marked changes over the 9-year period (Table 5). The exception was the plots that received ammonium sulphate where the pH was significantly lower in the 1981 samples collected at a depth of 0-15cm but not in the same plots at the lower depth.

Table 5. *Effect of nitrogen fertilizers on soil pH (Experiment 2)*

Treatments Depths (cm)	Soil pH			
	0-15		15-30	
Dates of sampling	1972	1981	1972	1981
Control	4.69	4.89	4.73	4.75
Ammonium sulphate	4.74	4.33*	4.69	4.62
Urea-forked in.	4.82	4.84	4.78	4.76
Urea-broadcast	4.79	4.80	4.67	4.71
LSD (P=0.05)	0.32	0.28	0.23	0.19

The sulphur status of the soil in Experiment 2 as indicated by its SO_4 content showed some changes resulting from the fertilizer treatments (Table 6), the SO_4 content in the plots given ammonium sulphate being significantly higher than in the urea-treated and control plots at both depths.

Table 6. *Effect of nitrogen fertilizer on SO_4 content of the soil (Experiment 2)*

Treatments	SO_4 content (mg/kg soil)	
	Depth (cm)	
	0-15	15-30
Control	92.4	130.5
Ammonium sulphate	141.6*	378.0*
Urea-forked in	97.3	188.7
Urea-broadcast	101.3	146.1
LSD (=0.05)	30.2	67.5

The SO_4 content of the rubber soils of Sri Lanka investigated in Experiment 5 showed (Table 7) significant variations ($P=0.01$) between different soil types. The values ranged from a mean of 570.5 in the Parambe soils to 58.5 mg/kg soil at Agalawatta. The pH values of the same soils (Table 7) also varied between the soil series and 16 mean values of from 4.5 to 5.1 were inversely related to the SO_4 content of the soil in this study.

Table 7. *Variation in the SO_4 content and pH of the rubber soil at depths of 0-30 cm (Experiment 5)*

Soil series	SO_4 content (mg/kg soil)		
	Range	Mean	pH Range
Boralu	69 - 239	117.5	4.5 - 4.6
Agalawatta	11 - 104	58.5	4.8 - 5.1
Parambe	209 - 985	570.5	4.4 - 5.0
Ratnapura	69 - 496	379.3	4.5 - 4.8
Homagama	39 - 247	113.8	4.8 - 5.1
LSD (P=0.05)	—	228.0	—
P=0.01)	—	325.5	—

Effect of nitrogen fertilizer on soil urease activity Experiment 2: Urease activity of soil was determined by the method of Hoffmann (1963) as modified by Bhavanandan and Fernando (1970) and expressed as urease number, which gives the quantity of urease contained in 100 g oven-dried soil. The urease number 1 corresponds to the quantity of enzyme in 100 g soil which hydrolyses 1 mg nitrogen as ammonia from urea. Table 8 gives the urease activity in soils sampled from Experiment 2 in December 1981.

Table 8. *Effect of nitrogen fertilizers on soil urease activity (Experiment 2)*

Treatment	Urease numbers	
	Range	Mean
Control	10.56 - 36.41	22.53
Ammonium sulphate	3.94 - 33.24	28.42
Urea - broadcast	32.13 - 58.46	46.56*
Urea - forked in	26.98 - 54.80	43.40*
LSD (P=0.05)	—	12.01

The urease activity has been significantly influenced by the urea fertilizer treatments. The activity in the entire experimental area ranged from 3.94 to 58.46 with the highest mean value of 44.5 in the plots that received urea. The mean values in the control and the ammonium sulphate plots were 22.52 and 28.42, respectively.

Effect of different forms of nitrogen fertilizers on loss of nitrogen by volatilization Experiments 3 and 4: The laboratory investigation (Experiment 3) carried out to determine the losses of ammonia from volatilization when nitrogen fertilizers were applied to rubber soils showed (Table 9) that the quantities of nitrogen lost from urea broadcast on the surface of rubber soils can be considerable and that these losses were related to the soil moisture level. The mean cumulative losses from a urea fertilizer recorded over a period of 15 days increased from 5.25 to 7.36 and 12.12% with increasing soil moisture. These losses were much lower with ammonium sulphate, the corresponding values being 2.75, 3.06 and 9.83%. The total cumulative loss of nitrogen, without considering the differences in moisture levels showed that 58% more nitrogen was lost from urea than from ammonium sulphate.

Table 9. *Effect of different soil moisture levels on ammonia volatilization from nitrogen fertilizers (Experiment 3)*

Soil moisture level (%WHC)	Mean cumulative N losses (mg N/100 g soil)		
	Urea	Sulphate of ammonia	Mean
0 - 5	5.25	2.75	4.00
45 - 50	7.36	3.06	5.21
95 - 100	12.17	9.83	11.0
Mean	8.26	5.21	—

The loss of nitrogen from the Matale soils was much heavier than from the other five soil types tested, from both urea and ammonium sulphate fertilizer (Table 10). With all soils, more N was lost from urea than from ammonium sulphate.

Table 10. *Effect of nitrogen fertilizers on loss of nitrogen (mg N/100 g soil in 15 days) (Experiment 3)*

Soil series	Mean cumulative loss of N (mg N/100 g soil)		
	Urea	Ammonium sulphate	Mean
Boralu	4.14	1.82	2.98
Agalawatta	4.22	2.16	3.19
Parambe	4.48	2.62	3.55
Ratnapura	4.40	2.30	3.35
Homagama	3.64	2.28	2.96
Matale	23.27	6.18	14.73

Field Experiment 5 carried out to study the losses of ammonia from urea and ammonium sulphate applied by either broadcasting or forking in at a depth of 15 cms, showed a significant interaction ($P/0.05$) between the forms of nitrogen and the methods of their application (Table 11). Urea, when broadcast, loses significantly more N through volatilization than does ammonium sulphate but when forked into the soil there is little difference between the two fertilizers.

Table 11. *Effect of nitrogen fertilizers and their methods of application on cumulative loss of nitrogen (Experiment 4)*

Sources of nitrogen	Broadcast	Mean cumulative loss of N forked in
Urea	5.22	0.89
Ammonium Sulphate	2.95	1.1
LSD ($P=0.05$) = 1.74		

DISCUSSION

This study indicates that application of nitrogen to rubber in Sri Lanka may be beneficial but needs to be done with discrimination. The poor response to applied nitrogen during the latter period of immaturity in experiment 1 may have been due to the mineralisation of organic nitrogen from the decaying leguminous covers. It is therefore possible that application of nitrogen may not be required under these conditions during the first few years of maturity. This suggestion is further supported by the satisfactory leaf nutrient levels observed in plants that received inorganic nitrogen fertilizers from the time of planting (Tables 3 and 4). Application of nitrogen fertilizers resulted in increases in leaf N to such levels that response to nitrogen application was unlikely under our condition (Yogarathnam and Silva, 1977). On the other hand the yield increases observed with application of nitrogen fertilizers in experiment 2 (Table 2), showed that the plants that had not received any nitrogen fertilizers from 1972 were obviously deficient in nitrogen, as can also be seen from the low values for leaf nitrogen concentration recorded in these control plants (Table 4). Further as the fertilizer treatments did not increase the girthing of trees, higher leaf nitrogen concentration in plants that received nitrogen fertilizers confirmed the uptake of nitrogen from applied fertilizers.

A comparison of the two sources of nitrogen revealed that urea was as effective as ammonium sulphate in increasing girthing of immature plants when both fertilizers were forked into the soil (Table 1). However, when urea was applied by broadcasting on the

soil surface (Experiment 2) it was less effective in increasing yields of rubber (Table 2). This was probably due to a reduction in uptake of applied nitrogen as indicated by the low leaf nitrogen values (Table 4) from the plants that received broadcast application of urea, possibly due to volatilization losses. In our laboratory (Experiment 3) it was found that 58% more nitrogen was lost by volatilization from urea than from ammonium sulphate. Similar losses have been reported by other workers (Martin and Chapman 1951 Wagner and Smith 1958 and Watson, Chin and Wong, 1962).

As it is evident that broadcasting urea is inefficient it becomes important to devise ways and means of overcoming this problem in order to take advantage of the economic benefits linked with the use of this fertilizer. Soil pH, moisture level and methods of application in the field were all found to influence volatilization in this study. Table 10 shows that high losses were experienced from the Matale series soil, with its pH of 6.5 and where soil formation has been influenced by the drainage of lime-rich solutions from adjacent outcrops of crystalline limestone (Silva, 1969). It is suggested that these may have been due to the alkaline reaction of dolomite on the ammonium carbonate formed from urea. Volatilization would be more noticeable if urea stayed on the soil surface in close contact with dolomite than if the urea was washed below the soil by rain before being converted to ammonium carbonate, as the insoluble dolomite would have less influence on the conversion. We have also shown in Experiment 2 that large changes in pH may not occur under field conditions in the other types of soil where urea is applied at comparatively low levels.

The extent of the ammonia loss was also found to be related to the soil moisture levels in the laboratory Experiment 3 (Table 9). This result must however be interpreted with caution because, in order to obtain known moisture levels, the soil was initially air dried and the appropriate amounts of water then added. This operation might have altered the microbiological activity and with it the conversion of urea to ammonium carbonate, thus affecting the subsequent loss of ammonia. A further consideration under field conditions is the extent to which the fertilizer may be washed into the sub-soil if there is rain soon after application.

The methods used for measuring the loss of ammonia in the laboratory and in the field may not have been completely realistic because they introduced a somewhat artificial environment, which differed from that of the soil surface and which would be subject to errors due to leaching and nitrification. However, as Experiments 3 and 4 were comparative studies, the methods were considered adequate for routine measurements although too much importance should not be attached to the absolute values.

In field Experiments 2 and 4 it was shown that one successful method of decreasing the volatilization of ammonia was forking in the urea below the soil. This may well result in any ammonia evolved by decomposition of ammonium carbonate being absorbed by the cation exchange complexes of the soil before it reaches the surface by diffusion. Similar work done by Rajaratnam and Purushothaman (1973) on Malaysian inland alluvium soil of pH 5.6 and 60% WHC, also revealed that when urea was worked into the soil at a depth of 15 cm, loss of nitrogen was negligible.

The high urease activity in the soils treated with urea (Table 8) could be a direct effect caused by an increase in the ureolytic microbial population of the soil; because when urea is available as the source of nitrogen, the microorganisms may come to depend on

this source for their nitrogen supply. Similarly, the high SO_4 content in all the soils may also have been a direct effect of the continued use of ammonium sulphate as the source of nitrogen and the use of sulphur for disease control in rubber plantations. This is further supported by the data in Table 6 from Experiment 2. The normal range of SO_4 content for agricultural soils in other countries are; Nigeria 38, Kenya 31, Colombia 11, Philippines 27 and Surinam 89, mg/kg soil (Muller and Sissingh 1980). According to Beaufils (1961) the S/P ratio in the rubber leaf should be 0.8 - 1.2; a ratio greater than 1.5 indicates severe nutritional disorders.

To sum up, the evidence at our disposal suggests that urea fertilizer is quite as effective as ammonium sulphate. The loss of nitrogen as ammonia, from the ammonium carbonate to which urea is converted in the soil, can be reduced to a minimum under most conditions of soil and moisture if urea is placed below the surface of the soil possibly by forking. It should be noted that under the conditions of rainfall prevailing in most rubber growing districts, the present practice is already to incorporate all the fertilizers into the soil, either by pocketing or forking, in order to prevent loss by surface wash.

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