THE CURRENT THINKING ON THE SUBSTITUTION OF UREA FOR SULPHATE OF AMMONIA IN TEA PLANTATIONS

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The tea plant *Camellia sinensis* responds to high levels of nitrogen and the two leaves and the bud harvested for tea manufacture removes as much as 3.5 to 4.0 per cent nitrogen with each harvest. Thus a field yielding 2000 kg made tea/ha/year would remove as much as 70 - 80 kg N ha^{-1} $year^{-1}$. The Institute's fertilizer recommendations are based on data from long term field experiments, short term laboratory and field investigations and scientific observations. In addition the yield potential of the individual field are also considered in determining the quantum of fertilizer to be applied.

Nitrogen is applied to the crop exclusively as ammonium, either as urea or ammonium sulphate or both. In relation to the substitution of urea for ammonium sulphate the Institute carried out thirty two field trials in different agro-ecological regions. At the end of two cycles in 29 out of 32 trials, urea and sulphate of ammonia gave similar yields. In addition, ongoing field experiments started in 1979, comparing urea and sulphate of ammonia have also given similar yields up to now.

In order to supplement and confirm the results obtained from trials, further investigations were carried out on the transformation of these two fertilizers in acid tea soils with special reference to the following aspects:

1. Urea hydrolysis in tea soils
2. Volatilization losses in relation to urea
3. Efficiency of uptake of urea and ammonium sulphate by mature tea plants

4. Immobilization and mineralization of urea and ammonium sulphate in tea soils
5. Effect of urea and ammonium sulphate on acidification of tea soils
6. Effect of urea and ammonium sulphate on Potassium, Calcium and Magnesium status of tea soils
7. Effect of urea and ammonium sulphate on Sulphur status of tea soils and the tea plants
8. Effect of urea and ammonium sulphate on root starch reserves
9. Effect of herbicides on urea hydrolysis in tea soils
10. Fate of Biuret in tea soils

Urea hydrolysis in tea soils

Urea, $CO(NH_2)_2$ is an organic fertilizer containing 46% N and the prilled urea locally manufactured or imported contains less than 1.0 % Biuret. The enzyme urease is essential for the hydrolysis of urea to ammonium ions. Once hydrolysed, the ammonium ion (NH_4^+) derived from urea is chemically identical to that derived from ammonium sulphate. The ambient levels of urease present in tea soils are adequate to hydrolyze the applied urea fertilizers and takes less than 3 to 4 days to hydrolyse the equivalent of 100 kg urea N applied ha^{-1} $application^{-1}$ (Wickremasinghe, Sivasubramaniam and Nalliah, 1981).

Volatilization losses of applied urea

The gaseous Ammonia loss often talked about with urea application is insignificant in acid tea soils (pH 4.0 - 5.0), when urea based fertilizer are *uniformly broadcasted on the soil.*

$$\text{Urea} \xrightarrow[\text{Urease}]{\text{Water}} \text{Ammonium Carbonate} \xrightarrow[\text{pH (4.0-5.0)}]{\text{Acid soils}} \text{No volatilization of gaseous } NH_3$$

The transient pH increase associated with urea hydrolysis under such conditions can rarely increase the already acid soil pH (4.0 - 5.0) to 7.0 or above to bring about any significant NH_3 volatilization. Further, for the application of any fertilizer mixture, be it urea based or sulphate of ammonia based, the primary requirement is that the soil must be moist at the time of fertilizer application. No fertilizer should be applied when the soil is dry or during drought or during heavy rains. Fertilizers applied during heavy rains are vulnerable to run off losses as both urea and ammonium sulphate are completely soluble in water.

Because of the high Nitrogen content in urea (46% N) compared to ammonium sulphate (21% N) the bulk available for distribution in urea mixtures is small. Hence greater care and supervision is necessary during the broadcasting of urea based mixtures.

Efficiency of uptake of Urea and Ammonium sulphate by mature tea plants

Experiments carried out using N-15 labelled urea and ammonium sulphate confirmed that the efficiency of plant uptake and utilization of fertilizer Nitrogen from the above two Nitrogen sources were similar (Table 1) and they are equally efficient sources of Nitrogen for mature tea (Wickremasinghe, Nalliah and Paramasivam, 1984).

Immobilization and mineralization of Urea and Ammonium sulphate in tea soils

The short term effects of these two sources of Nitrogen were discussed in the preceeding sections and now let us look at their long term effects on soil fertility, acidity, sulphur status, etc.

Immobilization and mineralization of urea and ammonium sulphate were studied using N-15 labelled fertilizers. The results revealed that 10-12% of the applied fertilizer Nitrogen was immobilized from both N sources and were also mineralized to a similar extent thus confirming

TABLE 1 - Efficiency of utilization of N derived from fertilizer urea and ammonium sulphate of mature tea

Treatment	Harvest	Days after fertilizer application	Atom per cent ^{15}N excess			Per cent N derived from fertilizer (NdfF)			Per cent N derived from soil (NdfS)		
			Flush	3rd leaf	Mature leaf	Flush	3rd leaf	Mature leaf	Flush	3rd leaf	Mature leaf
Urea	1st	28	4.5	3.5	2.5	51.2	40.2	29.0	48.8	59.8	70.9
	2nd	49	3.9	3.6	2.2	45.9	41.4	25.0	54.1	58.6	74.9
	3rd	76	2.9	3.3	2.5	32.9	37.7	29.4	67.0	62.3	70.6
	4th	98	2.7	2.7	2.9	30.9	31.4	33.6	69.1	68.6	66.3
Ammonium sulphate	1st	28	4.7	4.1	2.2	53.7	46.7	25.4	46.3	53.3	74.5
	2nd	49	3.9	3.4	2.3	45.0	39.5	26.7	54.9	60.4	73.2
	3rd	76	2.9	3.2	2.4	33.3	36.5	27.8	66.6	63.4	72.2
	4th	98	2.7	2.8	3.1	30.7	32.5	35.5	69.3	67.5	64.5

that both sources of Nitrogen behave very similarly as the short and long term fertility of the soil is concerned (Wickremasinghe, Rodgers and Jenkinson, 1985).

Effect of Urea and Ammonium sulphate on soil acidity and leaching of Potassium, Calcium and Magnesium

Any ammonium fertilizer, be it urea or ammonium sulphate when nitrified in the soil ($NH_4^+ \longrightarrow NO_3^-$) by nitrifying bacteria releases hydrogen ions to the soil solution. Any process that leads to the release of hydrogen ions to the soil acidifies the soil because the soil pH which determines the degree of soil acidity is dependent on the concentration of hydrogen ions in soil solution.

$$pH = -\log_{10} (H^+)$$

By virtue of the chemical transformations of urea and ammonium sulphate and the greater release of hydrogen ions to the soil solution associated with ammonium sulphate, the potential acidification of the soil with ammonium sulphate is fifty per cent more than that with urea as explained below.

Urea

(1) $CO(NH_2)_2 + H_2O \xrightarrow[\text{Hydrolysis}]{\text{Urease}} NH_4COONH_2$

(2) $NH_4COONH_2 + H_2O \longrightarrow (NH_4)_2CO_3$

(3) $(NH_4)_2CO_3 \longrightarrow 2NH_4^+ + CO_3^{--}$

(4) $CO_3^{--} + 2H_2O \longrightarrow H_2CO_3 + 2OH^-$

(5) $NH_4^+ + 3(O) \xrightarrow[\text{Oxidizing Bacteria}]{\text{Ammonium}} NO_2^- + H_2O + 2H^+$

$NO_2^- + (O) \xrightarrow[\text{Oxidizing Bacteria}]{\text{Nitrite}} NO_3^-$

Net acidity 2H per Urea Molecule i.e. 1H per N Atom

Ammonium sulphate

(6) $(NH_4)_2SO_4 \longrightarrow 2NH_4^{+} + SO_4^{--}$

(7) $NH_4 + 3(O) \xrightarrow[\text{Oxidizing Bacteria}]{\text{Ammonium}} NO_2^{-} + H_2O + 2H^{+}$

$NO_2^{-} + (O) \xrightarrow[\text{Oxidizing Bacteria}]{\text{Nitrite}} NO_3^{-}$

Net acidity 4H per $(NH_4)_2SO_4$ molecule i.e. 2H per N Atom.

Results from the long term field experiments dating as far back as 1955 to date show that soil pHs of plots treated with ammonium sulphate have been always significantly lower than those treated with urea (Tables 2, 3, 4) thus confirming the increased acidification of the soils with ammonium sulphate (Bhavanandan and Sunderalingam, 1971; Sandanam, Sivasubramaniam and Rajasingham, 1980; Wickremasinghe, Ananthacumaraswamy and Amarasekera, 1985).

Continuous use of ammonium fertilizers, especially ammonium sulphate, over the past few decades has resulted in the already acid tea soils becoming more and more acidic and certain plantations are recording soil pH values as low as 3.8 and 3.7. Despite the high soil acidity nitrifying bacteria in tea soils oxidize the ammonium nitrogen (NH_4 - N) to nitrate nitrogen (NO_3 - N). During this oxidation of the ammonium nitrogen, applied as fertilizer and/ or that mineralized by the soil organic matter, hydrogen ions are released to the soil.

$NH_4^{+} + 3\ (O) \xrightarrow[\text{Oxidizing Bacteria}]{\text{Ammonium}} NO_2^{-} + H_2O + 2H^{+}$

$NO_2^{-} + (O) \xrightarrow[\text{Oxidizing Bacteria}]{\text{Nitrite}} NO_3^{-}$

TABLE 2 - *Effect of urea and ammonium sulphate on soil acidity (pH)*

Source of N	N level (kg/ha/year)	Soil pH (0-15 cm depth) 1955	MAR 1966	FEB 1970	Decrease in 15 years
Urea	168	4.80	4.71	4.34	0.46
	336	4.80	4.36	4.31	0.49
Ammonium sulphate	168	4.80	4.31	4.04	0.76
	336	4.80	3.86	3.79	1.01

(Bavanandan and Sunderalingam, 1971)

TABLE 3 - *Effect of forms of N fertilizer on soil pH*

Experimental No.	SA	Urea	Date of pH determination	LSD (P=0.05)
XA 1	4.40	4.79	20.3.72	0.22
XA 2	4.26	4.75	24.4.72	0.34
XA 3	4.31	4.61	17.4.70	0.38
XA 4	4.37	4.60	29.3.71	0.27
XA 6	4.71	4.91	14.5.71	NS
XA 8	4.08	4.59	1.3.72	0.25
XA 10	4.22	4.51	14.3.71	0.23
XA 13	4.80	5.36	1.5.72	0.25
XA 14	4.94	5.48	15.8.74	0.48
XA 15	4.42	4.60	19.4.71	NS

(Sandanam, Sivasubramaniam and Rajasingham, 1980)

TABLE 4 - *Effect of urea and ammonium sulphate on soil acidity (pH)*

Soil depth	N level kg/ha/year	(pH) Urea	S.A.
0-15 cm	100	4.7	4.2
	200	4.5	4.1
	300	4.2	3.9
15-30 cm	100	4.4	4.1
	200	4.3	4.0
	300	4.2	3.9
30-45 cm	100	4.3	4.0
	200	4.3	4.1
	300	4.0	3.9

(Wickremasinghe, Ananthacumaraswamy and Amarasekera, 1985)

The hydrogen ions so released enhance the leaching of basic cations (K, Ca, Mg) with percolating rain waters, making the already acidic soils more and more acidic. In areas of heavy rainfall, surface runoff and leaching losses of bases also contribute to the soil acidity. The soils treated with ammonium sulphate release more potassium and magnesium to the soil solution than that treated with urea (Wickremasinghe, Nalliah and Wijedasa, 1985).

Despite the fact that tea thrives in acid soils (pH 4.1 - 5.0) we have to be cautious when soil pH falls below 4.0 because at a soil pH of 3.9 and below, the degeneration of the clay minerals begin to occur with the release of oxides of aluminium and silicon. This breakdown of the clay mineral directly affects the cation exchange capacity resulting in poor nutrient retention as well as leading to soil compaction and poor aeration.

The above results clearly show the ill effects of higher soil acidity in relation to overall soil fertility and in this respect in already acidic tea soils the use of sulphate of ammonia as a source of fertilizer nitrogen further aggravates the situation owing to the inherent greater acidifying properties of this fertilizer compared to urea.

Effect of urea and sulphate of ammonia on sulphur status of tea soils and the tea plant

Sulphate of ammonia by virtue of its chemical composition has 24% sulphur and 21% N compared to urea which has no sulphur and 46% N. The continuous use of sulphate of ammonia in tea plantations over the past few decades has added more sulphur to the soils than nitrogen and as a result there is a build up of sulphur in tea soils. A long term field trial testing urea and sulphate of ammonia, now in its 6th year (Field No. 16A in St Coombs), shows, that even with 100% urea application over the past six years the sulphur status of both the mature leaves and the flush were very similar (0.31 to 0.32 and 0.38 - 0.39% S respectively) for either treatment (Table 5).

TABLE 5 - Effect of urea and ammonium sulphate on sulphur status of the mature leaf and flush

N level kg N/ha/application	% S in mature leaf		% S in flush	
	SA	Urea	SA	Urea
112	0.31	0.31	0.41	0.35
224	0.32	0.33	0.36	0.36
336	0.34	0.34	0.39	0.39

The fact that Sulphur status in the leaves - flush and mature leaves were not influenced by neither the source of Nitrogen i.e. urea or sulphate of ammonia nor the rates of application (112, 224, 336 kg N ha^{-1} $year^{-1}$) despite their exclusive use over the past six years, reconfirms that the Sulphur reserves in the soils are more than adequate.

Soil analysis revealed that there was substantial amounts of plant available SO_4-S. The total sulphur and sulphate sulphur levels in the soil, are in the range of 1900 kg total S/ha and 500 kg SO_4 sulphur/ha in the 0-15 cm soil layer. It is also interesting to note that total S and sulphate sulphur increase with depth i.e. in 15-30 and 30-45 cm soil depth the available sulphate sulphur amounts to 924 and 1056 kg SO_4-S/ha, even in those plots receiving only urea (Table 6).

Thus on the whole the available SO_4-S in 0.-45 cm soil depth alone amounts to 2479 kg SO_4-S ha^{-1} which is nearly 2.5 metric tons of SO_4-S ha^{-1} (Table 7).

Sulphur removal with the harvesting of tea crop is very small i.e. 12-15 kg per every 3000 kg made tea ha^{-1} $year^{-1}$ which when compared with the available sulphate sulphur in the soil is negligible.

TABLE 6 - *Sulphur status in the soil with continuous use of urea for six years (St Coombs - Field No. 16A)*

Soil depth	N level kg/ha/year	SO_4 - S mg/ha Urea	SO_4 - S mg/ha SA	Total - S mg/ha Urea	Total - S mg/ha SA
0-15 cm	112	227	582	870	1191
	224	253	678	1125	1512
	336	270	692	837	1637
15-30 cm	112	452	569	1146	1117
	224	420	720	1262	1812
	336	450	687	1162	1637
30-45 cm	112	593	624	1271	1475
	224	486	667	1462	1892
	336	478	687	1625	1667

LSD 0-15 cm = 128 (P=0.01)
15-30 cm = 59 (P=0.01)
30-45 cm = 52 (P=0.01)

LSD 0-15 cm = 446 (P=0.01)
15-30 cm = 444 (P=0.01)
30-45 cm = 365 (P=0.01)

TABLE 7 - *Sulphur brought down by rainfall at different locations in Sri Lanka (kg/ha)*

Location	January	February	March	April	May	June	July	August	September	October	November	December	Total
Amparai	0.6	1.3	1.4	1.3	0.0	N.R.	0.7	0.1	2.2	1.1	1.3	0.8	10.8
Bandarawela	0.2	0.5	0.9	0.7	0.4	0.2	1.4	0.4	1.6	1.3	0.9	0.4	8.9
Batalagoda	0.3	0.1	2.0	1.4	0.8	0.9	0.6	0.2	1.1	2.1	6.4	1.4	17.3
Bombuwela	0.5	0.4	2.9	3.5	3.8	1.9	0.9	1.8	1.5	2.2	1.1	3.4	23.9
Gannoruwa	N.R.	N.R.	1.0	1.4	1.0	2.0	1.4	1.2	1.3	1.5	1.7	0.8	13.3
Karadian Aru	0.5	0.7	0.5	0.6	0.4	0.2	6.0	0.2	1.8	1.2	1.4	1.1	14.6
Maha Illuppallama	0.0	N.R.	0.4	1.6	0.5	0.1	0.8	0.2	1.2	0.9	0.7	0.6	7.0
Murunkan	0.2	N.R.	N.R.	0.4	0.7	0.2	0.3	N.R.	0.4	0.5	1.1	1.1	4.9
Paranthan	0.2	0.6	0.3	0.4	1.2	N.R.	2.0	N.R.	2.0	1.9	2.3	0.4	11.3
Sita Eliya	N.R.	2.2	0.9	0.5	0.8	1.2	1.7	0.9	2.1	1.2	0.9	0.3	12.7

N.R. = No Rain

(Amarasiri and Lathiff, 1982)

Leaf fall from the tea (tea leaf litter) and foliar application of Zinc Sulphate also contributes 5-6 kg S ha^{-1} $year^{-1}$.

In addition 8 to 12 kg of Sulphur is returned to the soil annually with rain (Table 7) (Amarasiri and Lathiff, 1982).

In addition *soil sulphur status of tea plantations and adjoining jungle areas from different agro-ecological regions* were monitored to ascertain the sulphur availability. The results show that in all the areas sampled, tea soils contained relatively large quantities of SO_4 -S when compared to the jungle soils (Table 8).

Effect of urea and ammonium sulphate on root starch reserves

Root starch reserves were found to be more in the plants treated with urea compared to those treated with ammonium sulphate and were found to decrease with increase in the rate of Nitrogen application (Krishnapillai and Pethiyagoda, 1979).

Effect of Herbicides (Gramoxone, Karmex and Roundup) on urea hydrolysis in tea soils

None of the above herbicides at their normal recommended concentration or even at concentration ten times higher failed to retard urea hydrolysis in tea soils. This confirms that there should be no reservations for the ground application of urea based fertilizer mixtures even immediately after the application of herbicides (Table 9) (Wimaladasa and Wickremasinghe, 1985).

Fate of Biuret in tea soils

Biuret ($H_2N - \overset{O}{\overset{\|}{C}} - \overset{H}{\overset{|}{N}} - \overset{O}{\overset{\|}{C}} - NH_2$) found as an impurity in urea (less than 1.0%) was found to be broken down by soil micro-organisms in tea soils. Hence the question of Biuret accumulation in the soil with continuous

TABLE 8 - *Sulphur status of soil under forest and tea cultivation in different tea growing areas*

Location	Depth (cm)	SO_4 - S (kg/ha) Jungle	Tea
St Coombs	0-15	48.0	431
	15-30	112.0	695
	30-45	202.0	888
	45-60	270.0	994
Hantane	0-15	68.0	77
	15-30	59.0	248
	30-45	68.0	150
	45-60	64.0	141
Kottawa	0-15	6.8	282
	15-30	59.0	365
	30-45	103.0	491
	45-60	70.0	629

TABLE 9 - *Effect of Herbicides on urea hydrolysis in St Coombs soil*

Treatment	Herbicide concentration	Concentration of unhydrolysed urea-N g/g soil with time					
		Hours					
		0	24	48	72	96	120
Diuron	Normal recommendation	1000	400	150	133.33	116.66	100
	Ten fold increase	1000	350	166.6	91.66	91.65	83.33
Paraquat	Normal recommendation	1000	316.45	150	91.65	91.65	83.33
	Ten fold increase	1000	416.65	150	93.33	91.65	83.33
Glyphosate	Normal recommendation	1000	300.00	133.33	100.00	100.00	91.65
	Ten fold increase	1000	450.00	250.00	150.00	133.33	110.66
Control	No herbicide	1000	333.00	150.00	100.00	83.33	65.00

use of urea leading to the build up of phytotoxic levels does not arise in tea soils (Fernando, Wickremasinghe and Goonetilleke, 1985).

Based on the above experimental observations and findings coupled with the additional financial benefits derived with the use of urea, owing to the lower cost per unit of Nitrogen compared to ammonium sulphate, the Institute is recommending that the entire Nitrogen requirement of the crop be given as urea.

The author believes that this article would help to clear any reservations and/or misconceptions in connection with the use of urea based fertilizer mixtures for mature tea.

REFERENCES

AMARASIRI, S.L. and LATHIFF, M.A. (1982). The Sulphur Deposition by rainfall in some agriculturally important areas of Sri Lanka. *Trop. Agric. 138*, 33-43.

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

KRISHNAPILLAI, S. and PETHIYAGODA, U. (1979). Effect of forms and levels of nitrogen on the growth and root starch reserves of young tea plants *(Camellia sinensis L.)* grown in sand culture. *Trop. Agric. (Trinidad) 56*, 205-211.

FERNANDO, V., WICKREMASINGHE, K.N. and GOONETILLAKE, R.B. (1985). Fate of Biuret in tea soils. (*S. L. J. Tea Sci.* - in press).

SANDANAM, S., SIVASUBRAMANIAM, S. and RAJASINGHAM, C.C. (1980). Response of seedling tea to forms and levels of nitrogenous fertilizers, levels of Potassium and liming in the up country tea growing districts of Sri Lanka. *Tea Q. 49, 20-29.*

WICKREMASINGHE, K.N., SIVASUBRAMANIAM, S. and NALLIAH, P. (1981). Urea hydrolysis in some tea soils. *Plant and soil 62*, 473-477.

WICKREMASINGHE, K.N., NALLIAH, P. and PARAMASIVAM, S. (1984). Comparative study of the efficiency of utilization of urea and ammonium sulphate by mature tea plants using N-15 labelled fertilizer. *Tea. Q. 53*, 23-28.

WICKREMASINGHE, K.N., RODGERS, G.A. and JENKINSON, D.S. (1985). Transformations of nitrogen fertilizers in soil. *Soil Biol. and Biochem. 17*, 625-630.

WICKREMASINGHE, K.N., NALLIAH, P. and WIJEDASA, M.A. (1985). Effect of urea and ammonium sulphate on nitrification and release of Potassium, Magnesium and Calcium in acid tea soils. *S. L. J. Tea Sci 54*, 11-17.

WICKREMASINGHE, K.N., ANANTHACUMARASWAMY, S. and AMARASEKERA, A. (1985). Effect of urea and ammonium sulphate on sulphur status of tea soils, tea plants and soil acidity. *S. L. J. Tea Sci* (in press)

WIMALADASA G.D. and WICKREMASINGHE, K.N. (1985). Effect of herbicides (Gramoxone, Karmex and Roundup) on urea hydrolysis in tea soils. *S. L. J. Tea Sci* (in press).