PERIODICAL CHANGES IN SOIL REACTION DUE TO INCORPORATION OF GREEN MANURE TO A DEGRADED TEA SOIL OF THE MID- COUNTRY OF SRI LANKA

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ABSTRACT

Some of the lands under tea in the mid-country of Sri Lanka were abandoned since three decades as marginal/degraded lands due to their poor performances. Soil acidity has been identified as a decisive factor for low soil fertility. For reclamation of such lands, application of liming is frequently advocated. However, as much of these lands are allocated to poor settlers , the procedure of liming is less appropriate.

This study has attempted to evaluate the effect of green manures in reducing the acidity of a degraded tea soil in view of reducing the cost of liming. A pot incubation experiment was conducted by treating the soil separately with CaO, Ipil-Ipil (*Leucaena leucocephala*) , Gliricidia (*Gliricidia sepium*) and Wild-sunflower (*Tithonia diversifolia*) green manure at a rate representing 5 t ha^{-1}. The duration of the incubation was 12 weeks and soil samples were drawn at 1st, 2nd, 3rd, 4th ,8th and 12th week subsequent to incorporation of materials.The samples were checked for pH, H^+- and Al^{3+}- saturations as well as pH buffering fluctuations.

Based on the results it could be concluded that the green manures used have made a significant contribution in reducing the acidity of the soil including the Al^{3+}-saturation. However, there were hardly differences between the green manures.No change was recorded pertaining to the pH buffering behavior of the soil as well. The overall effect in increasing the pH by green manure was around 1 unit where as the effect by CaO was 1.6 units. Hence there is a possibility of partial substitution of liming materials with appropriate green manures. It is useful to study the effectiveness of such combinations in the future.

INTRODUCTION

A considerable extent of land belonging to tea plantations in the mid-country of Sri Lanka had been neglected for about 3 decades due to unsatisfactory performances. These soils had been subjected to severe erosion and to a natural degradation process which lead to ecological, economical as well as sociological drawbacks. The reduction of the vegetation cover as a result of continuing degradation deteriorates the fertility of these soils further. Such lands are been categorized as marginal or degraded tea lands . However, due to limitations of arable lands it is inappropriate to lose such lands because of the present degraded status.

As a measure of conserving these lands from further degradation and providing lands for the landless, the government has allocated large extents of such lands in the form of 1 - 2 acre allotments to poor settlers. The settlers have been requested to introduce crops like pepper and coffee alongside other garden crops such as vegetables (Malik,1991). The National Agricultural and Diversification and Settlement Authority (NADSA)was handed over the responsibility of launching the rehabilitation program .In the process of distribution of the lands , due attention was not given to the fertility status but only to the land area. Around 40% of the land area formerly under tea in the Kandy District have been allocated for such other land uses.

At present,these degraded soils are characterized by considerably high aluminium saturations, low base saturations , acidic pH levels and low organic matter contents. It has also been highlighted that the soil acidity related parameters are primarily responsible in limiting the fertility of these soils (Botschek et al.,1994).The pH values of the degraded tea lands are frequently less than 5 and the base saturations less than 50%. There are instances also where Al^{3+}- saturation exceeds H^{+}-saturation, indicating the possible aluminium toxicity to crops except for aluminium tolerant tea.

Inspite of the extreme low fertility the settlers are trying hard to introduce mixed cropping patterns as frequently advocated by numerous organizations without much success. The most frequently suggested measure to reduce the acidity is application of liming materials. However, this seems not practically appropriate due to the cost of the materials and transport,as well as quantities (around 3 - 5 t ha^{-1}) needed.

Hence, the present study has attempted to monitor the periodical changes that may occur in relation to pH, H^{+}- and Al^{3+}- saturations as well as pH-buffering ability by incorporation of green manure to a representative degraded tea soil. The main aspect was to evaluate the possibility of addition of green manure in view of partial substitution of costly liming materials.

MATERIALS AND METHODS

A soil catena of the Nilambe Oya catchment in the Uda Palatha Division of the Kandy District, Sri Lanka was selected for the investigation as a representative location for degraded tea lands. The average annual rainfall and the temperature of the area are 2900 mm and 22.5 ^{o}C respectively. The location selected for sampling was situated at an elevation of about 700 m above mean sea level.

A composite soil sample was prepared from the above location by extracting soil from the A-horizon of which the depth was fluctuating between 10 to 20 cm.Samples collected from 10 points of the catena were pooled together and air dried and passed through a 2 mm sieve. A representative subsample was separated and characterized for major properties prior to the study. A pot incubation experiment procedure was adopted for the experimentation and the experiment was conducted in a polythene tunnel constructed at the Department of Soil Science, University of Peradeniya to simulate green house conditions.

pH values of aqueous extracts (1:2.5) of fresh leaves of some green manure species were measured and *Leucaena leucocephala, Gliricidia sepium and Tithonia* *diversifolia* were selected for the investigation as their pH values were 6.45,6.25 and 7.27 and these are been frequently used in the region.

500 g of soil were filled into each plastic pot and chopped green manure leaves were separately incorporated at a rate representing 5 t ha^{-1}. Soil without any additions, and added with a similar rate of calcium oxide served as controls for comparisons. Thus the treatments in the experiment were soil only, soil with *Leucaena*, soil with *Gliricidia*, soil with *Tithonia* and soil with calcium oxide. Each treatment was replicated thrice and the moisture level of each pot was maintained at 60% of maximum water holding capacity by daily weighing and irrigating with distilled water.

The duration of the incubation was 12 weeks and soils were periodically sampled after 1, 2, 3, 4 ,8 and 12 weeks of the establishment of the experiment. These periodically drawn samples were then analyzed for changes in pH, exchangeable H^+ and exchangeable Al^{3+} (including ions in the soil solution) as well as pH buffering ability. The pH was measured potentiometrically using a combined glass electrode in a soil : 1NKCl (1:2.5) suspension . Determination of total acidity (H^+ and Al^{3+} ions) was conducted titrimetrically with sodium fluoride as suggested by Pagel (1981) and the pH - buffer curves were established by measuring pH using additions of different volumes of N/30 $Ca(OH)_2$ solution to the samples.

RESULTS AND DISCUSSION

Some important characteristics of the soil used are given in the Table 1.

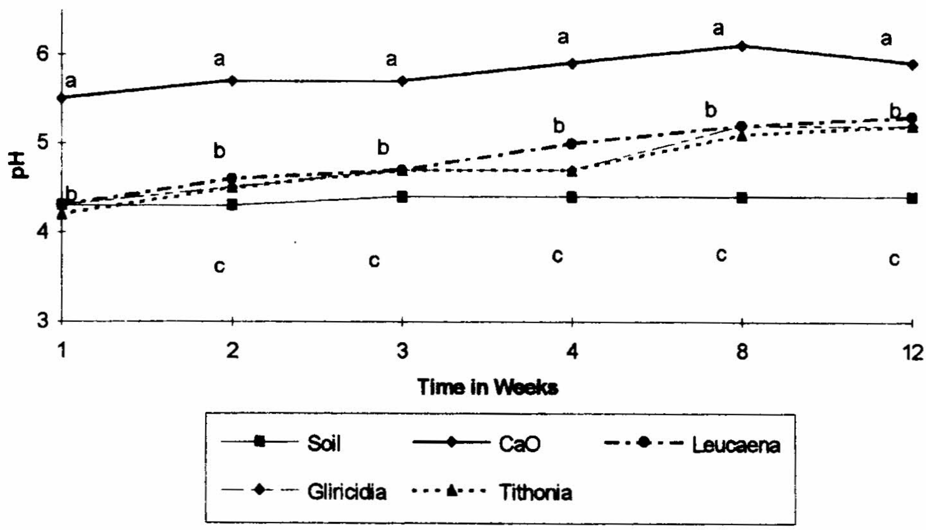
According to the soil map of Nilambe Oya catchment prepared by Wijesuriya (1992), this soil is a Red Yellow Podsolic Soil (Tropudalt). The soil under study was strongly acidic (Table. I). The leaching of bases by heavy precipitations and also by application of ammonium sulfate as a nitrogen fertilizer to tea for many decades have created this situation (Wickramasinghe, Nalliah and Wijedasa, 1985). The observed total acidity of 1.79 me 100 g soil $^{-1}$ had to be considered as a result of such activities.

The acidification may have also spread much deeper into the soil profile due to the observed course texture. Such a situation was reported by Botschek et al.,1994. Around 30% of the exchange complex was occupied by H^+ and Al^{3+} where Al^{3+}-saturation was much higher than the H^+ -saturation. Under such situations, the nutrient imbalances of the crops grown are inevitable. Hence there could be disorders in the plants resulting in an overall poor growth as experienced by settlers at present and also as reported by Cochrane, Salinas and Sanchez,1980. However, tea bushes seem to tolerate these levels to a certain extent (Mengel and Kirkby, 1987). Observed poor growth of plants in the location is closely related to the above phenomenon. The Cation Exchange Capacity (CEC) of the soil is very low though there is a moderate level of organic matter; perhaps due to less humic matter formation . Fassbender (1972) has also reported about a possible inhibition of organic matter transformation in acidic soils.The moderate base saturation of the soil is of a very limited significance as the CEC is very low. Hence this soil possesses a very low fertility.

Table 1 . Some important properties of the soil used

PROPERTY	VALUE
Sand (%)	86.36
Silt (%)	5.64
Clay (%)	8.00
pH (1:2.5 1N KCl)	4.27
pH (1:2.5 H_2O)	4.85
CEC (me / 100 g soil)	6.60
Base saturation (%)	72.88
Total C (%)	0.80
Total N (%)	0.11
C:N - ratio	7.27
Organic matter (%)	1.37
H+ saturation (%)	10.91
Al^{3+} saturation (%)	16.21
Total acidity (me / 100 g soil)	1.79

As illustrated in the Figure 1 it was evident that the pH of the soil subjected to green manure incorporations showed an increasing tendency.



Same letters given at a time is not significantly different at 5%

Fig.1. Periodical changes of pH in treatments

The pH of the soil without any additions remained more or less constant lying lower than the treated soils throughout the experimentation. The experiment has clearly indicated the ability of used green manures to increase the pH of this extremely acidic soil in a short period of time.Perhaps the lower pH buffering ability of the soil due to coarse texture and moderate organic matter content may have eased the change.The differences observed between the unamended control and the amended soils were significant.Wade and Sanchez (1983) have indicated similar effects due to addition of green manure to acidic soils. However, there were no significant differences between different green manure treatments.The pH increases were 1.78, 0.80, 0.93 and 0.95 units due to the incorporation of calcium oxide, *Leucaena, Gliricidia* and *Tithonia* respectively. The overall effect in pH increase by green manures at the 12th week was around 1 unit where as the effect by calcium oxide was around 1.6 units.

The periodical changes of total acidity are illustrated in the Figure 2.

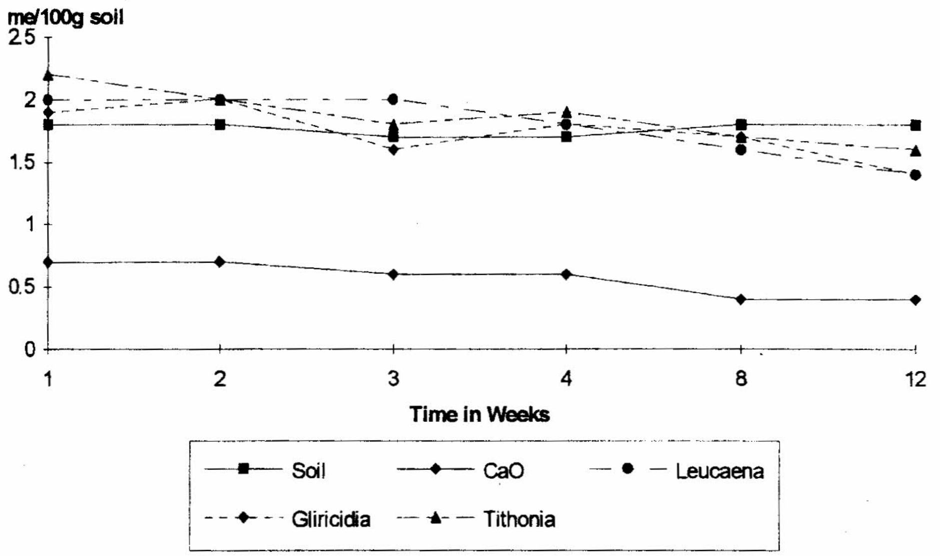


Fig.2. Periodical changes of total acidity (Al^{3+}+ H^+) in treatments

The total acidity of untreated soil showed a higher value at the end of the incubation. However, the acidities of green manure treated soil were considerably higher than that of the untreated control at the 2nd, 3rd and 4th weeks sampling though not significant. This trend was reflected in the periodical changes of H^+ and Al^{3+} separately as well (Tables II and III).

Table II. Periodical changes of H^+ (me/100g soil) in different treatments

Treatment	Weeks					
	1	2	3	4	8	12
Soil only	0.74^a	0.75^a	0.68^{ab}	0.73^a	0.74^a	0.72^a
CaO	0.34^b	0.30^b	0.27^c	0.28^b	0.21^c	0.22^c
Leucaena	0.82^a	0.88^a	0.83^a	0.75^a	0.64^b	0.56^b
Gliricidia	0.79^a	0.87^a	0.76^a	0.74^a	0.71^{ab}	0.58^b
Tithonia	0.95^a	0.98^a	0.72^a	0.78^a	0.69^{ab}	0.59^b

Values with the same letter in a column are not significantly different at 5%

Table III. Periodical changes of Al^{3+} (me/100g soil) in treatments

Treatment	Weeks					
	1	2	3	4	8	12
Soil only	1.07^a	1.10^a	0.99^a	1.01^a	1.06^a	1.10^a
CaO	0.39^b	0.35^b	0.31^b	0.32^b	0.19^b	0.26^b
Leucaena	1.20^a	1.15^a	1.21^a	1.07^a	0.93^a	0.81^c
Gliricidia	1.20^a	1.14^a	0.88^c	1.08^a	1.03^a	0.82^c
Tithonia	1.08^a	1.06^a	1.05^a	1.17^a	1.01^a	0.86^c

Values with the same letter in a column ar not significantly different at 5%

This could have been due to the formation of H^+ at the start of the decomposition of green manure and later due to the complexation of Al^{3+} with intermediate products of decomposition thereby restricting the hydrolysis of Al^{3+} to introduce H^+ ions to the environment. The overall effect at the end was a substantial reduction of exchangeable H^+ and Al^{3+} which has also most probably stimulated the promotion of the increase of base saturation. The cations released by the green manures may have occupied the exchange sites earlier occupied by H^+ and Al^{3+} ions. Henry and Forth (1984) has reported such a phenomenon. Al^{3+} ions may get complexed to form chelates (Mortenson,1963, Wade and Sanchez, 1983). Chelating ability of organic matter may be the most important function here. Reduction of total acidities of acidic soils by green manure additions has been reported by Bear and Firman (1964).

The drastic reduction of exchangeable acidity in calcium oxide treated soil ,was due to the Ca^{++} ions present as well as the neutralization power of the liming material due to formation of calcium hydroxide in the aqueous medium.

The periodical changes in the pH buffering of the unamended soil alongside the *Leucaena* treated soil is illustrated in the Figure 3 to represent the effect of green manures as the patterns of the changes in pH-buffering of *Gliricidia* and *Tithonia* treated soil were not at all different to the curves illustrated here.

No contrasting changes in pH-buffering by any green manure added were observed during the 12 weeks of incubation, suggesting that the effect of green manure was mainly that of neutralizing and Al^{3+} complexation nature by chelation. However, there was a minute trend in increasing the buffering ability by green manures. Such an effect could help to maintain the pH of soils when little changes in concentrations of H^{+}or OH^{-} ions occur.

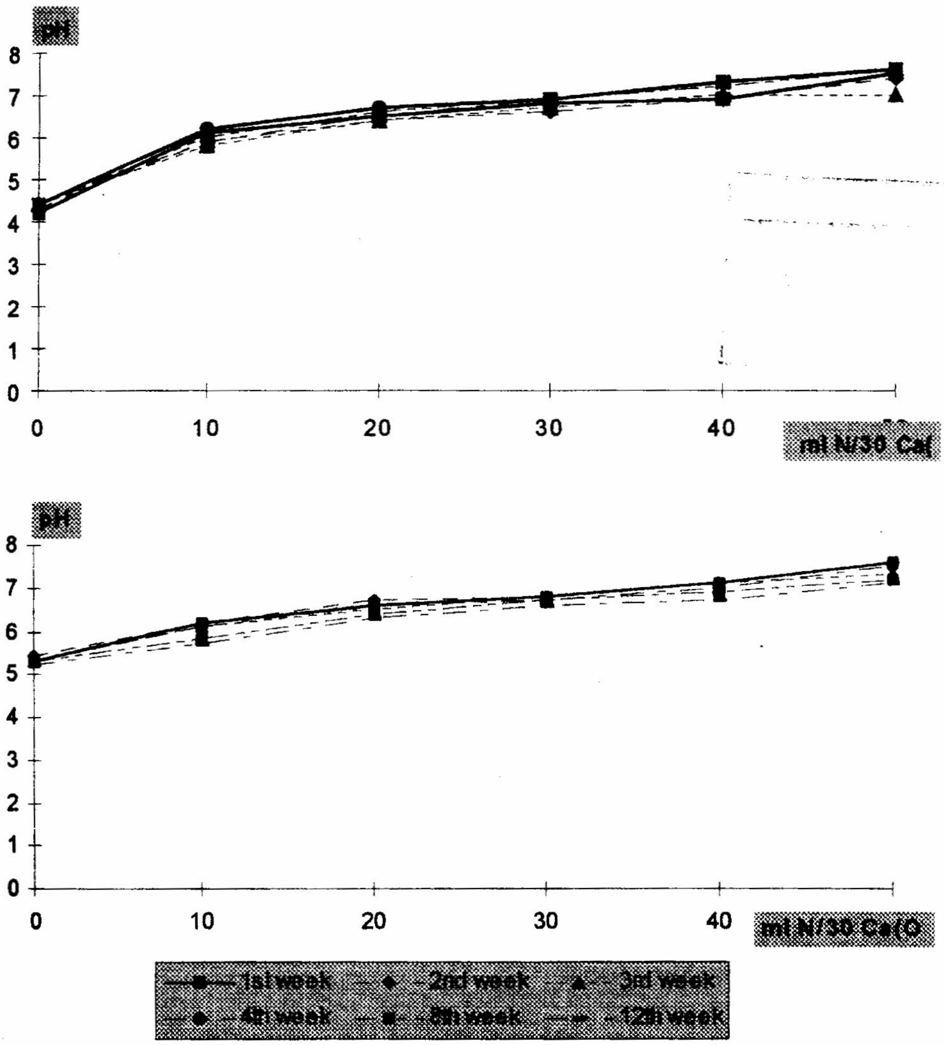


Fig. 3 . pH Buffer curves for the soil only (upper) and *Leucaena* treatment (lower).

CONCLUSIONS

It could be concluded that the present acidity of the soil affects the growth of crops negatively and hence the soil is not suitable enough to be exploited for high nutrient demanding crops though the climatic conditions could be favorable. As acidity of the soil is decisive , this situation has to be improved by adopting practically appropriate procedures. Green manures such as *Leucaena, Gliricidia* and *Tithonia* would contribute appreciably to decrease the soil pH as well as total acidity by reducing toxic levels of aluminium. This positive contribution should be taken into consideration when suggesting liming as combined applications would be much appropriate in reducing the cost of liming as well as in avoiding possible lime induced nutrient deficiencies in plants.However it would be useful to study further pertaining to the effectiveness of different types and amounts of green manure combinations with liming materials .

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