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Original Article

Calcium in Soils and its Relevance to Tea Cultivation

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Abstract

The importance of Soil pH maintenance to optimize Calcium content in soil for keeping optimum Calcium content in tea tissues for unrelenting good performance of its physiological functions vital to have sustainable productivity levels for economic survival of tea industry.

Keywords

Calcium in Soils; Soil pH; Plant Needs and Removal and Replacement.

Introduction

Tea Is a calcifugous crop. It requires only a small amount of calcium mainly for its role in the compound composition of bio-mass, mostly of the cell wall. A higher calcium concentration particularly in leaf tissues interferes with photosynthesis as it has developed a mechanism involving Potassium and silicon for Carbon-di-oxide assimilation and release during its evolution in base deficient humid conditions. The optimum Ca content in leaf tissues is between 0.6 and 0.8 for efficient photosynthesis .Also a minimum Ca concentration in soil solution is required for uptake of nutrients by roots and to reduce leakage of nutrients from root.

High calcium in soil solution increases ca content in leaf tissues resulting in dislocation of photosynthetic process leading to decline in productivity. Low calcium content in soil solution leads to heavy metal toxicity mainly that of Iron and Manganese. A soil pH of 4.8 to 5.0 ensures soil Calcium levels at optimum ones to maintain a leaf Calcium content at desired levels for efficient photosynthesis. Therefore all efforts are made to maintain the pH at around 4.8 (between 4.5 and 5.0).

All recommendations on correcting pH with liming in acid soils and gypsum in alkaline soils are based on base saturation concepts to maintain pH in the range 6.0 to 7.0.Schofield and Taylor (1955) developed lime potential using activity ratios of both H^+ and Ca^{2+} ions i.e., pH–1/2 pCa =k . This formed the basis of many lime recommendation models .Most of the crops grow well in this pH range. But Tea is one of the crops which require a pH range between 4.5 and 5.0 for optimum performance of photosynthetic process for high productivity. Over long years of cultivation in humid zones most of the tea soils have reached pH levels below 5,5. For soils with pH above 5.0, applications of S, FeSO4, or $Al_2(SO_4)_3$ are used to bring down the pH below 5.0 and thereafter regular liming program is adopted to maintain the pH between 4.5 and 5.0. Gypsum is avoided as it is insoluble in acidic medium.

To rationalize the lime application in relation to export of it away from the system the economic end product as commercial tea and the thick wood portions at pruning as fire wood and, losses thru leaching and run-off as against the amount required to maintain soil the amount required to maintain soil physicochemical properties to maintain the tilth of the soil, Calcium removal from the system through different pathways are reviewed for defining a need based liming program for tea crop. Liming is done usually once in a pruning cycle before or after the prune by broad casting method. Sometimes one more mid cycle lime application is done if needed in extended pruning cycles as in high elevations. The prunings are spread over applied lime to reduce its

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losses in the runoff during rains and make it dissolve faster with the action of organic acids released during their decomposition.

Loss of Calcium

It occurs through runoff water and that is taken by the plants for their growth. Only a portion of nutrients taken by the plants are retained in the field mainly as leaf fall. Most of them are taken away from the system for commercial purposes and animal feed. A review is made to rationalize liming recommendations over the existing ones for tea areas in South India based on soil pH and crop needs.

Base Saturation

Soil available Calcium content is related to pH and pH is related to base saturation of clay exchangeable sites. Soils turn acidic as bases are removed by uptake by plants and also by leaching by percolating water downwards and away from the system in the runoff water during rains. As Calcium forms the bulk of bases in the soil, it is customary to express total amount of bases in terms of Calcium Carbonate equivalence. Base saturation in soil clays decreases with time due to leaching of bases with irrigation or rain water aggravated by intensive cultivation practices. It is governed by First order Kinetics.

$A_n = A\ (1-k)^n$.............1

Where A_n – *base saturation at nth year.*
A-base saturation at the beginning,
k-the rate of loss of bases, n-the time in years (k=0.10 at PH 7 to 5, and 0.15 at PH below 5.0 k-increases 2 to 4 times with intensity of cultivation and rainall

In the PH range below 5.0, every 5% drop in base saturation is associated with 0.1 unit drop in PH and it is 3% in pH range between 5.0 and 7.0. Under intensive cultivation a drop in PH of 0.1 occurs in a period of 3 to 4 years due to accelerated rate of leaching of bases

Net loss of bases /year from the system depends on rainfall, soil pH and binding strength of cations, steady state equilibrium at mid portions of large are where export and import of them occurs and, through crop removal of which major portion is exported away from the system as economic end products for which they are grown. The quantification of losses through various path ways is made to rationalize the liming program in tea cultivation which is a calcifuges crop grown in humid acidic soils.

At pH below 5.0, the common range of pH in tea soils of South India, the loss of bases in terms of calcium carbonate for every drop in 0.1 unit pH (5% drop in base saturation) for 30 cm depth of soil of bulk relative density of around 1.1 ($3*10^6$ kg soil) and at an average base exchange capacity 5 meq % comes to 413 kg $CaCO_3$ per ha. The above figures could be expressed by the final equation given below: Loss of bases (as Ca CO_3) = BEC *DBS*16.5
Where 'BEC' is Base Exchange capacity (meq%) and 'DBS' is the % drop in base saturation.

Time taken for base saturation to be halved ($n^{1/2}$) rapidly falls with the intensity of cultivation as could be seen from Table 1 given below:

It explains how the intensive cultivation has accelerated acidification of soils

Intensity of cultivation is defined in terms of quantum of irrigation, fertilizer use, density of plants

Table 1: Impact of intensity of Cultivation on rate if fall in base saturation

Entry	Intensive Cultivation (after l 1955)			Regular Cultivation(up to early 1950/1960			
k	0.15	0.10	0.05	0.020	0.015	0.010	0.005
$n^{1/2}$yr	4.3	6.8	13.5	34.3	45.9	69.0	138.3

Intensity of cultivation is defined in terms of quantum of irrigation, fertilizer use, density of plants and crop husbandry practices for a sustainable/targeted productivity level . 'k ' is the rate of loss of bases; $n^{1/2}$yr-number of years for base saturation to be halved;

Table 2: Loss of bases in runoff water with and without use of fertilizers

MS	Annual rainfall cm/yr	Runoff water %	Runoff water m^3ha^{-1}	BASES content PPM	Loss of bases kg/ha/yr
1*	350	31.5	$1.1x10^4$	2.5	27.5
2*	350	31.5	$1.1x10^4$	5.0	55.0

Bases in terms of equivalent calcium carbonate *MS – cultivation management System
1*- No fertilizer cultivation management :
2*-With fertilizer cultivation management

Table 3: Calcium assimilated per ha by Tea crop in kg for every 1000 kg made tea produced

	Shoot *a*	Mature leaf *b*	Small stem *c*	Thick wood *d*	Roots *e*	Total *f*	Export g
Mean % distribution of bio-mas	21	17	13	30	19	100	64
Calcium assimilated in kg	3.7	11.7	3.2	10.3	4.8	33.7	17.2

a-Shoots used for tea manufacture ; b-Annual leaf fall and foliage at pruning retained recycled as green manure in the field itself: c and d – removed from the field for fuel; f-total assimilated for producing 1000kg made tea; g- net removal from the system (a +c + d) Calcium removed away from the system in terms of Calcium Carbonate - 43 kg (17.2*2.5) for every 1000kg made tea produced.

Table 4: Loss and gain of Bases in Tea cultivation System (as Calcium Carbonate KG /ha /year)

	Particular	No fertilizer management a	With fertilizers management b
Losses 1	Crop removal	43	108
Losses 2	Run off water	28	55
Lime replacement	Total kg /ha/year	71	163
Liming rate- once [in a pruning cycle	3 year cycle	213	489
	4 year cycle	288	652
	5 year cycle	355	815

and crop husbandry practices for a sustainable/ targeted productivity level. 'k ' is the rate of loss of bases ; $n^{1/2}$yr-number of years for base saturation to be halved.

Loss Through Runoff Water

There is little export of bases away from the system through irrigation water except for local disturbances in the distribution of nutrient ions against plant uptake. As the soil surface potential retains the cations with the concentration gradient tailing off from the surface to the bulk of soil solution. As such only the cations in the diffuse double layer and the soil solution, which are mutually exchangeable freely, are removed in the runoff water The content of bases in runoff water varied from 15 to 30 PPM with an average of 20 PPM.

The quantum of runoff water depends on the intensity of rainfall. The South-west monsoon brings soaking low intensity rainfall spread over more number of days than the North-east monsoon notorious for heavy showers and landslides. Vegetation, Soil depth, and permeability reduce the runoff by 30 %.

Runoff estimated from soil conservation experiments extensively carried out during 1930-1940 by various organizations is 30% for South –west monsoon rains and 70 % for North-east rains. In tea areas of South India, the average runoff is 45% taking into account the proportion of rainfall received in the both the monsoons.

The net runoff is 31.5 % i.e., 45 % of (100-30). As both export and import of nutrients occur in mid areas of the slope losses occur at top areas of the slope .The resultant load of base in runoff entering the stream at the bottom of the slope is less than 5 ppm well within the norms stipulated under environmental pollution regulations (Table 2)

Uptake of Calcium and its Removal from the System

Calcium content of various parts of tea plant and the amount taken away from the system are shown in Table 3. Calcium (as Calcium carbonate) removed away from the system is 43 kg for every 1000 kg tea manufactured for sale.

Annual Total Loss of Calcium from Tea Fields

Losses of Calcium both from crop removal and through run-off water are given in Table 4. Crop removal depends on productivity levels of the fields and it is quantified for every 1000 kg tea manufactured. Losses through rain-water depends on the quantum of rain –fall , intensity of spells and rainy days and, the intensity of cultivation defined in terms of quantum of irrigation, fertilizer use, density of plants and crop husbandry practices for a sustainable/targeted productivity level. As liming is done once in a pruning cycle, the quantity of lime to be applied is to be calculated for the length of the cycle from the annual removal from the system

Liming Recommendation

The rational approach to liming in tea gardens is to bring down the soil pH to the optimum range of 4.5 to 5.0 wherever it is required based on soil tests with traditional recommendations and then try to maintain the pH at the desired range by replacing the quantities exported away from the system.

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