Agric. Res. J. Kerala, 1983, 21 (2), 15-22

CARBON - NITROGEN RELATIONSHIP IN LATERITE SOILS OF KERALA*

P. B. Usha and A. I. Jose

College of Horticulture, Vellanikkara 680 654, Trichur, Kerala

Soii organic matter is the pool of nutrients that is accessible to plants. The proportion of different elements in soil organic matter may differ with respect to the degree of decomposition, stabilization with other soil compounds, the quality make up of the organic residues and soil conditions under which the soii organic matter is synlhesised into a comparatively stable form. Soil nitrogen is mainly present in organic form and therefore nitrogen values are worked out from the organic carbon content of the soil especially in advisory soil testing programmes. It is highly essential that precise relationship between organic carbon and total or available nitrogen should be worked out for different types of soil which differ in the quantity and quality of organic matter contained in them before fertilizer recommendations are made based on organic carbon values.

Materials and Methods

In order to establish the relationship between soil organic carbon and soil nitrogen precisely, 490 surface soil samples (0–15 cm depth) representing the upland laterite areas of different districts of the stale were selected for the study by screening a large number of soii samples coliected, assuring variation in the content of organic carbon, total nitrogen and texture of the soil.

Soils were grouped into different classes based on the content of organic carbon and soil texture. Based on the level of organic carbon present, soils were grouped into: (1) low organic carbon group with organic carbon less than 1.0 per cent. (2) medium organic carbon group with organic carbon 1.0 to 2.0 per cent; and (3) high organic carbon group with organic carbon more than 2.0 per cent and based on texture soils were grouped into: (1) sand; and (2) loam/clay

Organic carbon was determined by the method of Walkely and Black total nitrogen by microkjeldahl method (Jackson, 1958) and available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956). Mechanical analysis of these soils was done by hydrometer method as described by Piper (1942). The data were examined statistically making use of the principles of correlation and regression as described by Panse and Sukhatme (1967).

Part of the M. Sc (Ag) thesis submitted by the senior author to the Kerala Agricultural University, 19S2,

Results and Discussion

Data relating to the general characteristics of the soils are presented in Table 1. The soiis collected were acidic and non-saline. The relationship between different properties and their regression equations are given in Table 2.

The pH of the soil was significantly and negatively correlated with the total organic carbon, total nitrogen and available nitrogen. Increased accumulation of organic matter in soil tended to decrease the soil pH due to release of organic acids during the decomposition of organic matter (Russell, 1963). The electrical conductivity of the soil was found to be significantly and negatively correlated with pH in the same category of soils. In this type of soil, due to extreme leaching and drainage, the amounts of exchangeable ions and soluble salts retained in soil are very negligible and, as a result, these soils register low values for electrical conductivity and relatively higher values for soil pH due to decreased presence of hydrogen ions and hence the negative correlation between pH and E. C. The day content of the soil was found to be significantly and positively correlated with the organic carbon content of the soil ($r=0.1282^{*}$) when all the soils were pooled. However, organic carbon and clay content were not significantly correlated in different groups of soil examined separately. Conditions which help the accumulation of clay fraction also favour the accumulation of organic matter since both are mainly colloidal in nature.

Data (ranges and mean) relating to the content of organic carbon, total nitrogen and available nitrogen of soil and their ratios are presented in Table 1.

Organic carbon:

The contents of organic carbon and total nitrogen in soil were highly correlated ($r=0.7966^{**}$). Organic carbon was also correlated with available nitrogen ($r=0.4008^{**}$) though not to the extent of that between total nitrogen and organic carbon.

Total nitrogen:

The total nitrogen of the soil ranged from 0.026 to 0,534 per cent. The total nitrogen content increased with increase in organic matter. The mean values for total nitrogen in the low, medium and high organic carbon groups of soil were 0.090, 0.149 and 0.253 per cent respectively. Loam and clay soils retained large amount of total nitrogen than sandy soils.

Available nitrogen:

The content of available nitrogen ranged from 0.004 to 0.038 per cent. Available nitrogen in the low, medium and high organic carbon groups of soil were 0.012, 0.016 and 0,024 per cent respectively. Also, clay/loam soils contained large amounts of available nitrogen as compared to sandy soils. When the sand group of

Table 1

General characteristic of soils (ranges and means)

Soil properties	All soils	Organic carbon group			Textural group	
		Low	Medium	High	Sand	Loam/clay
PH	4.20-7.60 (5.94)	4.75-7.60 (6.04)	4.20-7.20 (5.85)	4.60-7.30 (5.75)	4.60-7.60 (6.12)	4.20-7.4 (5.86)
E. C. mmhos/cm	0.003-1.570 (0.165)	0.005-1.260 (0.144)	0.005-1.570 (0.138)	0.003-0.820 (0.152)	0.005-1.570 (0.146)	0.003-1.370 (0.194)
0. C%	0.21-4.87 0.25)	0.21-0.99 (0.71)	1 00-2.00 (1.34)	2.01-4.87 (2.82)	0.21-3.19 (1,03)	0,32-4.87 (1.31)
N%	0,026-0.534 (0.138)	0.026-0.165 (0.090)	0.053-0.319 (0.149)	0.099-0.534 (0.253)	0.026-0.417 (0.113)	0.032-0.534 (0.151)
aN%	0.004-0.038 (0.016)	0.004-0.027 (0.012)	0,004-0.037 (0.016)	0.004-0.038 (0.024)	0.004-0.028 (0.014)	0.004-0.038 (0.058)
Clay%	1.6-46.2 (16.49)	1.6-36,3 (15.12)	1.6-46.2 (16.65)	4.8-39.1 (19.38)	1.6-11.6 (8.86)	4.8-462 (20.98)
C/N	4.17-25.44 (9.23)	4.68-25.44 (3.9)	4.17-20.80 (9.68)	5.58-20.52 (11.26)	4.68-19.74 (9.11)	4.17-25.44 (9.25)
C/aN	18.62-436.22 (81.68)	13.62-165.31 (60.87)	31.67-282.76 (94.30)	34,12-436,28 (131.87)	18.62-436.22 (95.25)	27.57-317,98 (80.65)
N/aN	1.88-29.28 (9.24)	1.88-22.14 (7.74)	3.33-29.28 (11.17)	4.5-25,65 (12.52)	3.05-29.28 (10.78)	1.88-24.87 (9.13)

(The values in parenthesis are means)

Table 2

Relationship between different properties of soil

X	Y	r	Regression equations
All soils (n=490)			
Organic carbon	Total nitrogen	0.7963**	N% = 0.0803 C% + 0.0380
Organic carbon	Available N	0.4001**	aN% = 0.0053 C% + 0.0094
Organic carbon	Clay	0.1282*	Clay% = 1.661 C% + 14.4593
Totalnitrogen	Available N	0.4233**	aN% = 0.0556 N% + 0.0083
pH	Organic carbon	-0.2115**	C% = 0.2742 pH + 2.8743
pH	Totalnitrogen	-0.1806**	N% = 0.0236 pH + 0.2781
pH	Available N	-0.2045**	aN% = 0.0035 pH + 0,0368
Clay	Total nitrogen	0.1520**	N% = 0.0012 Clay% + 0.1172
Clay	Available N	0.1335**	aN% = 0.002 Clay + 0.0127
Low carbon soils (n=210)			
Organic carbon	Totai nitrogen	0.6376**	N% = 0.0959 C% + 0.0218
PH	Organic carbon	-0.1767*	C% = -0.0691 pH + 1.1286
Medium carbon soils (n=220)			
Organiccarbon	Total nitrogen	0 3800**	N% = 0.0696 C% + 0.056
Organic carbon	Available nitrogen	0.3217**	aN% = 0.0205 C% - 0,0114
Total nitrogen	Available nitrogen	0.3343**	aN% = 0,1161 N% - 0.0013
pH	Available nitrogen	-0.1981**	aN% = 0.1161 N% — 0.0013
High carbon soils (n=60)			
Organic carbon	Total nitrogen	0.4237**	N% = 0.0429 C% + 0.1320
Organic carbon	Available nitrogen	0.2708*	aN% = 0.0037 C% + 0.0136
Sandy soils (n=141)			
Organic carbon	Total nitrogen	0.7533**	N% = 0.0775 C% + 0.0329
PH	Organic carbon	-0.2223**	C% = -0.2346 pH + 2.4702
pH	Total nitrogen	-0.1887*	N% = -0.0205 pH + 0,2380
pH	E C.	-0.1680*	E.C. = -0.0578 pH + 0.5000
Clay	Available N	0.2751**	aN% = 0.0016 clay% + 0,0016
Loamy / clayey soils (n=349)			
Organic carbon	Total nitrogen	0.5878**	N% = 0,0743 C% + 0.0539

** Significant at 1% level * Significant at 5% level

Table 3

Relationship between soil properties and carbon-nitrogen ratios

X	Y	r	Regression equation
Organic carbon	C/N	0.3468**	C/N = 0,7072 C% + 8.3530
Organic carbon	C/aN	0.6128**	C aN = 4.8368 C% + 78.6629
Organic carbon	N/aN	0.8736**	N/aN = 2.1 742 C% + 6.8371
Total nitrogen	C/aN	0.3209	C/aN = 7.6569 N% + 83.5913
Total nitrogen	N/aN	0.4587**	N/aN = 3.4514 N% + 9.0788
Available nitrogen	C/aN	-0.2317**	C/aN = 19.6427 aN% + 84.9596
Available nitrogen	N/aN	-0.2671**	N/aN = 7.1401 aN% + 9.6427
Clay	C/aN	-0.1617*	C/aN = -0.3510 Clay% + 89.7532
Clay	N/aN	-0.1705*	N/aN = -0.1172 Clay% + 11.3778

** Significant at 1 % level
* Significant at 5% level

soil registered a mean value of 0.014 per cent for available nitrogen the corresponding value for clay loam group of soil was 0.068 per cent, the increase being 385.71 per cent. This showed that clay/loam group of soil was capable of retaining extremely large quantities of available nitrogen as compared to sandy soil. It should be pointed out that such a conspicuous difference between sandy soils and loam/clay soils was not seen in the case of total nitrogen though loam/clay soils contain relatively higher content of nitrogen than sandy soils. When sand group of soil registered a a mean value of of 0.1 13 per cent for total nitrogen, the corresponding value for clay and loam group was 0.152 per cent the increase being only 33.628 percent. Available nitrogen content of the soil was correlated with total nitrogen ($r=0.4233^{**}$), organic carbon ($r=0.4008^{**}$) and pH of the soil. The relationship beetween organic C and available nitrogen is not as high as the relationship between organic carbon and total nitrogen. This is because major part of total nitrogen is represented by organic nitrogen which is a component of organic matter as in the case of organic carbon whereas transformations and retention of available nitrogen are not governed by any such direct linkage with organic carbon.

C:N ratio

In general, C:N ratio of the soils ranged from 4.17 to 25.44 with a mean value of 9.23. The C:N ratio increased with the increasing content of organic carbon of the soil. The mean C:N ratios for the low organic carbon, medium

organic carbon and high organic carbon soils were 8.19, 9.68 and 11.26 respectively. The simple linear equation established considering all the soils taken for the study is N% = 0.0803C% + 0.038 (Table 2). This would mean that even soil containing no organic matter will contain 0.038 per cent nitrogen and obviously soil containing very little of organic carbon will have a low C:N ratio. In soils which retain only very low content of organic carbon. the organic matter has undergone a greater degree of oxidation thereby decreasing the ratio between carbon and nitrogen whereas in soils which are rich in organic carbon, the organic matter includes fractions which have not undergone the process of decomposition fully thereby exhibiting a higher C:N ratio. Considering the above regression model, a soil with 0.2, 1, 2 and 3 per cent organic carbon will have a C:N ratio of 3.70, 8.47, 10.05 and 10.75 respectively. The variation in the C:N ratio is getting narrowed down when the value for organic carbon is getting higher. In the present study regression equations between carbon and nitrogen have been worked out for groups of soil categorised according to the percentage of organic carbon. The regression equations presented in Table 2 showed that for low, medium and high carbon groups of soil the coefficients of regression were 0.0959, 0.0696 and 0.0429 respectively. The nitrogen content which does not vary with the organic carbon content (the constant of regression equation) is high for soils containing large amount of organic carbon than soils of low organic carbon content.

The C/N ratio of the soii was found to be positively and significantly correlated with the organic carbon (r=0.3466**) which indicated the increase in the content of organic carbon resulted in a corresponding increase in C/N ratio of soil. The negative correlation between total nitrogen and C/N ratio is not statistically significant indicating that variation in the nitrogen content of soil is not tune with the variation in the organic carbon.

Ratio between organic carbon and available nitrogen (C:aN)

The mean C/aN ratio is 8.849 times more than the mean C/N ratio of soil. The C/aN ratio of different groups of soil examined separately, revealed that the ratio overwhelmingly increased with the increasing content of organic carbon and its values in medium and high organic carbon groups were 94.3 and 131,87 respectively. The excessively inflated C/aN ratio in soils of high organic carbon content may be due to the fact that the soil could retain only a limited quantity of mineralised nitrogen and therefore loss of nitrogen due to leaching and denitrification became pronounced in soils where targe amount of nitrogen was released by mineralisation. The negative and significant correlation between clay per cent and C/aN (Table 3) is also indicative that the C/aN ratio is dependent on the retentive power of the soil The mean C/aN ratios for the sand and clay/loam groups of soil were 95.25 and 80.65 respectively- The decreased C/aN ratio in clay/loam soils is obviously due to increased accumulation of available nitrogen in this group of soi!. AS already pointed out the mean values for organic carbon in sand and

clay/loam groups of soil were 1.03 and 1 .31 per cent, the increase being 26.40 per cent whereas the mean values for available nitrogen in these two groups of **soil** were 0.014 and 0.68 per cent respectively, the increase being 385.71 per cent. These observations substantiate the influence of the finsr fractions of soil in decreasing the C/aN ratio of the soil.

Ratio between total nitrogen and available nitrogen (N:aN)

The ratio of total nitrogen to available nitrogen varied from 1 .88 to 29.28 with a mean value of 9.204, On an average, 10 82 percent of the total nitrogen was retained in soil in available form. The mean values of N/aN ratio in low, medium and high organic carbon groups of soil were 7.74, 11.17 and 12.52 respectively. The ratio increased with the increase in organic matter content of soil. This is because, though the content of available nitrogen increased with the increasing content of organic matter, the increase in available nitrogen was not in proprotion with the increase in organic carbon. The increase in the content of available nitrogen consequent to mineralisation of organic nitrogen is restricted by the limited adsorptive power of the soil thereby resulting in an enlarged N/aN ratio in soils of high organic carbon content. The clay loam group of soil registered relatively low value of N/aN ratio (9.13) as compared to sand group of soil.

Summary

Surface soil samples from 490 sites representing upland laterite areas of the different districts of Kerala were analysed in order to establish precise relationships between organic carbon and total as well as available nitrogen in these soils. As the acidity increased, the content of organic carbon, total nitrogen and availabte nitrogen (aN) in soils also increased. The content of organic carbon in soil was found to be significantly and positively correlated with the clay content ($r=0.1282^{*}$). Organic carbon content had positive and significant correlation with total nitrogen ($r=0.4008^{*}$) of soil. The C N ratio for low, medium and high organic carbon soils were 8.1 9. 9.63 and 1 1 .26 respectively. Simple linear equation for calculating total nitrogen based on organic carbon content of soil was worked out as $N\%=0.0803\ C\%+0.038$- C/aN ratio had positive and significant correlation with organic carbon ($r=0.6128^{**}$) and total nitrogen ($r=0.3209^{**}$). On an average, 10.82 per cent of total nitrogen in soil was retained in available form. The N/aN ratio increased with increase in organic carbon, but not in linear proportion.

സംഗ്രഹം

മണ്ണിൽ ജൈവ കാർബണും പാക്യജനകവും തമ്മിലുള്ള ബന്ധം നിർണ്ണയിക്കുന്നതിനായി കേരളത്തിലെ വിവിധ ജില്ലകളിൽനിന്നും **490** ഉപരിതല മൺ സാമ്പിളുകൾ ശേഖരിച്ച് രാസപരിശോധനയ്ക്ക് വിധേയമാക്കി. മണ്ണിലെ അമ്ളത മണ്ണിലടങ്ങിയിരിക്കുന്ന ജൈവ കാർബൺ, ആകെയുള്ള നൈട്രജൻ, സസ്യലഭ്യമായ നൈട്രജൻ എന്നിവയുമായി ധന

സഹബന്ധം പുലർത്തുന്നതായി കാണപ്പെട്ടു. നൈട്രജന്റെ അളവ് ജൈവ കാർബണിന്റെയും കളിമണ്ണിന്റെയും അളവുമായി ബന്ധപ്പെട്ടിരിക്കുന്നു. ജൈവാംശത്തിന്റെ അളവ് കുറവ്, ഇടത്തരം, കൂടുതൽ എന്നീ തരത്തിൽപെടുന്ന മൺ വർഗ്ഗങ്ങളിൽ കാർബൺ : നൈട്രജൻ അനുപാതം യഥാക്രമം 8.19, 9.68, 11.26 എന്നിവയായിരുന്നു. നൈട്രജനും കാർബണും തമ്മിലുള്ള ബന്ധം $N\% = 0.0803C\% + 0.038$ എന്ന ലഘു രേഖീയ സമാശ്രയണ സമീകരണംകൊണ്ട് സൂചിപ്പിക്കാവുന്നതാണ്. മണ്ണിൽ ആകെയുള്ള നൈട്രജന്റെ 10.82 ശതമാനം സസ്യലഭ്യ രൂപത്തിലാണ്.

References

Jackson, M. L. 1958. *Soil Chemical Analysis* Prentic Hall Inc., U. S. A. 183-190

Panse, V. G. and Sukhatme, P. V. 1976. *Statistical Methods for Agricultural Workers.* Indian Council of Agricultural Research, New Delhi, 97-128.

Piper, C. S. 1942. *Soil and Plant Analysis,* Hans Publishers, Bombay, 77-79

Russell, E. J. 1963. *Soil Conditions and Plant Growth*. Longman Green & Co. London, 316-321

Subbiah, B. V. and Asija, G. L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.* 25, 258-260