Nitrogen Enrichment of Soils of Vellayani by Monsoon Rains

K. BABUKUTTY[1] and A. P. A. BRITO-MUTUNAYAGAM[2]

Division of Chemistry, Agricultural College and Research Institute, Vellayani

Received for publication January 2, 1967

Ever since Liebig postulated that the accession of nitrogen in rain and snow was the principal source of combined nitrogen for soils, agricultural scientists have been interested in the composition of atmospheric precipitation. The best known among the pioneer investigations on the nitrogen content of rain are those undertaken at the world renowned Agricultural Research Station at Rothamsted. The analysis of rain water at Rothamsted was commenced in 1853 by Lawes and Gilbert the founders of this station and this work is being continued even now. The literature on the chemical composition of atmospheric precipitation is rather voluminous. Most of it, however, relates to countries in the temperate zone where the annual rainfall is much lower than in the tropics. Eriksson (1952) in a comprehensive review of 130 years, records dealing with nitrogen accession in atmospheric precipitation in Europe, showed that the inorganic nitrogen added varied from 0.74 kg/hectare in Stornoway (U. K) to 21.99 kg/hectare in Preskau (Germany) for annual rainfall of 1060 mm and 445 mm respectively. No accurate assessment of the amount of nitrogen brought down by monsoon rains in the humid tropics is possible because of insufficient data on soil nitrogen accretions from this source. Venema (1961) reported that the nitrogen content of rain in tropical countries ranged from 2.2 to 41.7 lb/acre per annum for widely varying amounts of precipitation. Koch (1941, 1943) found that an annual precipitation of 2850 mm at Peradeniya in Ceylon added 13.04 kg nitrogen/hectare, of which 7.82 kg was ammonia nitrogen and 5.22 kg nitrate nitrogen.

Very few studies have baen carried out in India to determine the amount of nitrogen added to the soil by monsoon rains. Leather (1906) was the first to undertake investigations on the composition of Indian rain. He recorded addition of 3.405 lb nitrogen / acre at Dehra Dun and 3.84 lb nitrogen/acre at Kanpur for annual rainfall of 86.4" and 49.6" respectively. Data compiled by Eriksson (1952) showed that 995 mm rainfall at Madras contributed 1.91 lb nitrogen/acre and 3950 mm precipitation at Sylhet supplied 8.80 lb nitrogen/acre annually. Vijayalakshmi and Pandalai (1962, 1963) are the only investigators who

1. Research Assistant
2. Professor, University Grants Commission Scheme.

have studied the composition of rainfall in Kerala. They reported that 2919.7mm precipitation received during a period of six months at Kasaragod, enriched the soil by 2.361 kg total inorganic nitrogen/hectare, 2.13 kg being ammonia nitrogen, 0.155 kg nitrate nitrogen and 0.0*76 kg nitrite nitrogen.

It is obvious that the amounts of nitrogen deposited in the soil by rain vary markedly in different parts of the world. Further, large year to year variations appear to be the rule both in the temperate and tropical zones. The available data, however, unmistakably indicate that nitrogen accretion from atmospheric precipitation may under some environmental conditions be of a magnitude that is of agronomic significance. There is evidence to show that location, amount of precipitation and atmospheric disturbances considerably influence the quantity of nitrogen added in rain. In view of the paramount importance of nitrogen in the maintenance of the fertility of Indian soils, an attempt was made to assess the contribution that rain may make to the nitrogen supply of soils of Kerala State where the average annual rainfall is 3300 mm and monsoon rains are often associated with thunder and lightning. It has to be borne in mind that the amount of nitrogen added by rain, however small it may be, is a net gain to the soil. Also, that this nitrogen is present in a readily available form unlike the combined nitrogen that enters the soil through other natural processes. There can be no question, therefore, that the nitrogen supplied by monsoon rains is of definite value to agriculture and is of special significance to many perennial crops and forest vegetation which seldom receive adequate nitrogen fertilization.

Experimental

This investigation was carried out at the Agricultural College and Research Institute Vellayani, which is located about 8 miles from Trivandrum City. Vellayani is 50 feet above mean sea level and about 3 miles from the coast. Like the rest of Kerala Vellayani gets the benefit of both the south west and north-east monsoons, The average annual rainfall in this station is 1800mm. Thunderstorms occur frequently in the pre-monsoon months of April and September. Vellayani has a tropical climate. The temperature is fairly uniform throughout the year. March, April and May are the hottest months, the mean monthly maximum temperature being of the order of 32.2° C.

Four rain gauges of standard dimensions, viz.. 15" height and 5" radius, were used in this study. Three of these were set up in different parts of the College Farm. The fourth was erected on the terrace of one of the main buildings in the campus about 30 feet above ground level. Care was taken to locate the rain gauges in open places, clear of trees and buildings to ensure that the water collected is not contaminated by terrestrial dust.

Samples were collected every day at 8 A.M. from all the four gauges after recording the rainfall. The analysis of a composite sample was carried out as far as possible on the day of collection itself. When the precipitation was scanty the samples were held over until sufficient quantity was collected. In such cases, a few drops of toluene were added to prevent any possible microbial activity during storage.

The present study was confined to the evaluation of three forms of nitrogen, viz.,

(i) ammonia, (ii) nitrate, and (Hi) nitrite. Standard methods of analysis of water jointly recommended by the American Public Health Association, American Water Works Association and Water Pollution Control Federation (1961) were adopted. Ammoniacal nitrogen was determined by the direct nesslerization method using a photometer providing a light path of 1 cm and equipped with a blue filter having a maximum transmittance of 400 - 425 μ. Nitrate nitrogen was estimated by the phenol disulphonic acid method using the same photometer. Nitrite nitrogen was determined by the α naphthylamine hydrochloride method and in this case the photometer was equipped with a green filter having a maximum transmittance of 520 μ.

Results and Discussion

Rainfall in Vellayani

The monthly distribution of rainfall in Vellayani during the period covered by this study, viz., September 1965 - August 1966, is shown in Table I.

The monthly precipitation fluctuated between 3·4 and 322.4 mm. December which is generally a month of low rainfall recorded the maximum precipitation. The rainfall during May and September was unusually low. The number of rainy days. per month ranged from 0 to 12. October registered the highest number of rainy days. February was a completely dry month. The intensity of rainfall varied from 3.4 to 40.3 mm per day.

The total precipitation recorded during the year was 1213.8 mm. This is far below the normal, the average annual rainfall in Vellayani being 1800 mm. More rain was received during the, north-east monsoon than the south-west monsoon which is very unusual. Variations in both monthly and annual distribution of rainfall are to be expected and may be ascribed to the vagaries of the monsoons which is a common feature of rainfall in Kerala.

Distribution of different forms of nitrogen in rainfall in Vellayani.

Data indicating the range of concentration of the different forms of nitrogen in rainfall in Vellayani are assembled in Table II.

Ammoniacal Nitrogen

The concentration of NH_3-N was much higher than that of NO_3-N and NO_2-N in all the rains received. This is in accord with the observations of Vijayalakshmi and Pandalai (1962, 1963) in Kerala, Leather (1906) in U. P., Bamber (1900) in Ceylon and several other workers in different parts of the world. It may be pointed out that the ammonia concentration in rain in temperate regions quoted by Eriksson (1952) is generally higher than that recorded in the present study. This is probably due to greater industrial activities and higher coal consumption in temperate countries.

The results show wide month to month fluctuations in the concentration of NH_3-N, the values ranging from 0.05 to 1,67 ppm. This is true of rainfall all over the world. Higher ammonia concentration was noted during the hottest months of the year, viz,, March to May, which is in conformity with the finding of Juritz (1914) that summer rains in South Africa contained more ammonia nitrogen than winter rains, Wilson (1921) observed that the ammonia content of rain water was high and low at periods corresponding to high and low biochemical activity in the soil. Das *et al*

TABLE I

Monthly distribution of rainfall in Vellayani

(September 1965 - August 1966)

Month	Number of rainy days	Rainfall mm	Intensity of rainfall/day mm
1965			
September	2	44.9	22.5
October	12	241.3	20.1
November	8	124.2	15.5
December	8	322.4	40.3
1966			
January	1	3.4	3.4
February	Nil	Nil	
March	2	37.0	18.5
April	6	81.8	13.6
May	2	31.0	15.5
June	11	206.6	18.8
July	5	87.0	17.4
August	2	34.2	17.1
Total	59	1213.8	—

TABLE II

Range of concentration of different forms of Nitrogen in rainfall in Vellayani

Month	NH_3-N ppm	NO_3-N ppm	NO_2-N
1965			
September	0.620 - 0.830	0.100 - 0.225	0 005 - 0.011
October	0.050 - 1.200	0.015 0350	trace 0.023
November	0.420 - 1.100	0.100 0.315	0.004 0.025
December	0.181 - 0.940	0.070 - 0.190	trace 0.025
1966			
January	0.950 -	0.530 -	0.008 -
February			
March	0.950 - 1.200	0.380 0.401	0.015 0.025
April	0.710 - 1.670	0.330 0.801	0.005 - 0.070
May	1.100 - 1.520	0.671 0.920	O.C62 - 0.082
June	0.060 1.000	0.020 0.310	trace 0.030
July	0.980 - 1.400	0.600 - 0.850	0.003 - 0,025
August	1.980 -	1.050 -	0.013 -

(1933) were of the view that during summer there was greater biochemical activity in the soil which enriches the atmosphere in ammoniacal nitrogen. Yasalon (1964) working in Israel reported that the concentration of NH_3-N in air increased four fold in the hotter months. These observations satisfactorily account for the seasonal variations in ammonia content of rainfall noted in the present study.

The ammonia concentration in rain is found to decrease as the precipitation increased. Harrison and Williams (1897), Koch (1941 1943) and many other workers have also recorded a similar relation between these two factors. In this investigation the data show a significant negative correlation (r = - - 0.406) between the concentration of Ammonia and the amount of rainfall.

There are also other factors which influence the concentration of NH_3-N in rain. It was observed that rains of short duration had a relatively higher ammonia concentration than rains which continued for long periods as reported by Meyer and Pampfer (1959). Further, that the concentration of NH_3-N was higher as the interval between two rains was longer. This seems to be due to greater replenishment of ammonia in the atmosphere with increasing time and this conclusion is in line with the observation made by Venema (1961) that ammonia in rain was at its highest concentration when a period of drought was followed by heavy precipitation.

Ammonia in rain may originate from the sea, soil or combustion of fuels. It cannot be categorically stated as to which of these is the major source of ammonia in atmospheric precipitation in Vellayani. Wilson (1959) claims that ammonia in rain has its ultimate source in the ocean. As this station is only 3 miles from the sea coast it is very likely that the influence of the ocean may be significant. The Vellayani Lake which adjoins the college campus may also make its own, though much smaller, contribution of ammonia to the atmosphere. The soil, particularly the submerged paddy lands in the college farm, may be yet another source of ammonia in rain as suggested by Das *et al* (1933). As there are very few industrial activities in and around Vellayani, the amount of ammonia nitrogen that may be released by the combustion of fuels may be insignificant.

Nitrate Nitrogen

The concentration of NO_3-N was much lower than that of NH_3-N in rain in Vellayani. This is in agreement with the findings of most other workers. Contrary results, however, have been reported by Harrison and Williams (1897) in Barbades and Harrison (1912) in British Guiana. These are rare exceptions which can only be ascribed to the peculiar environmental conditions in the places mentioned.

Unlike NH_3-N, the month to month concentration of NO_3-N varied within a narrow range, the values lying between 0.02 and 0.53 , ' This suggests that nitrate is less influenced by season than ammonia. Several investigators have found that a close relation exists between nitrate concentration and rainfall, In the present work a significant negative correlation (r — 0.742) was obtained between these two factors.

The NO_3-N values recorded in this study are in general higher than the figures reported for temperate region countries. Miller (1905) at Rothamsted and Leather (1906) in

TABLE III

Amounts of different forms of Nitrogen added in rainfall in Vellayani (September 1965 - August 1966)

Month	Rainfall mm	kg/hectare NH_3-N	NO_3-N	NO_2-N	Total N
1965					
September	44.9	0.333	0.076	0.004	0.413
October	241.3	0.400	0.194	0.019	0 613
November	124.2	0.907	0.276	0.035	1.218
December	322.4	1.223	0.394	0.029	1.646
1966					
January	3.4	0.019	0.018	0.001	0.038
February	Nil				
March	37.0	0.410	0.146	0.008	0.564
April	81.8	0.886	0.332	0.023	1.241
May	31.0	0.362	0.259	0.020	0.641
June	206.6	1.044	0.354	0.028	1.426
July	87.0	1.042	0.647	0.012	1.701
August	34.2	0.678"	0.360	0.004	1.042
Total	1213.8	7.304	3.056	0.183	10.543

TABLE IV

Different forms of Nitrogen in monthly rainfall in Vellayani expressed as percentage of Total Nitrogen

Month	NH_4-N. per cent	NO_3-N. per cent	NO_2-N. per cent
1965			
September	80.5	18 5	1.0
October	56.8	40.1	3.1
November	73.9	23.3	2.8
December	74.5	23.8	1.7
1966			
January	51.5	48.0	0.5
February		-	
March	72.8	25.8	1.4
April	73.3	24.8	1.9
May	56.5	40.4	3.1
June	73.2	24.8	2.0
July	61.3	38.0	0.7
August	65.1	34.5	0.4
Average	67.2	31.3	1.7

India also pointed out that tropical rains contained a higher percentage of nitrate nitrogen than non-tropical rains. Eriksson (1952), however, is doubtful whether the nitrate fraction in the atmosphere is higher in tropical places than in temperate regions.

Many workers have observed that NO_3-N increased during thunderstorms. This point was not specifically studied in the present investigation, but greater nitrate concentration was generally noted in rains received during April-May which were associated with severe lightning. As the frequency of lightning in Kerala is high, it would be reasonable to conclude that the nitrate in rain in Vellayani during particular seasons of the year may be largely derived from electric discharges in the atmosphere. As suggested by Rao *et al* (1931) and others another possible source of nitrate in rain is photochemical oxidation of ammonia which is favoured by atmospheric conditions in the tropics.

Nitrite Nitrogen.

Nitrite nitrogen in rain has seldom been reported. 1 ı is the smallest of the different categories of nitrogen and in some investigations has been automatically included in the determination of nitrate.

The nitrite concentration in rain is generally very low. In the present study it ranged from a trace to 0·082 ppm the majority of the values lying below 0'035 ppm. Higher concentrations were noted during April-May which is apparently due to the influence of temperature. This confirms the observation of Das *et al* (1933) that most of the nitrite in rain at Sylhet was delivered during the hot months of April-June.

NO_2-N is the intermediate unstable form of nitrogen in the oxidation of NH_3-N to NO_3-N. Both nitrite and nitrate in the atmosphere are believed to be derived from the same source.

Accession of nitrogen in rain in Vellayani

The amounts of inorganic nitrogen in different forms added in monthly precipitation in Vellayani are given in Table III.

It is seen from the data that 1213·8 mm rainfall received in this station during th'e year September 1965-August 1966 added to the soil 10·543 kg total nitrogen, comprising 7·304 kg NH_3 - N, 3.056 kg NO_3-N and 0·183 kg NO_2-N. This figure compares favourably with the values quoted by Eriksson (1952) for flive Indian stations which range from 1·91 kg nitrogen/hectare in Madras to 8.80 kg nitrogen/hectare in Sylhet for annual rainfall of 995 mm and 3950 mm respectively. He estimated that nitrogen accession in atmospheric precipitation in Europe averaged 7·2 lb/acre per annum.

Vijayalakshmi and Pandalai (1962, 1963) reported that 2919.7 mm rain received during a period of six months in Kasaragod in Kerala contributed only 2.361 kg total inorganic nitrogen/hectare. Their estimate is extremely low compared to the value obtained in the present study. In fact, it is less than the recorded values for all Indian stations except Madras where the annual rainfall is only one-third that at Kasaragod. It may be noted in this context that Kasaragod and Vellayani are 350 miles apart but both are situated near the sea coast. Further, the annual precipitation in Kasaragod is considerably higher than that in Vellayani. Other meteorological conditions at these two stations are much the same. In the light of these facts, it would be reasonable to expect much greater accession of inorganic nitrogen in rain in Kasaragod than in Vellayani. The results reported, however, appear contradictory and need elucidation.

The largest contribution of total nitrogen was made in December the month which recorded the maximum rainfall and the lowest in January the month which registered the minimum precipitation. A significant positive correlation (r = 0·706) was observed between the amount of nitrogen added and the monthly rainfall. Tracy (1895), Trieschmann (1919) and Wilson (1921) found a similar relation between these two faetors.

Relation of different forms of nitrogen to total nitrogen in rain in Vellayani

Data showing the amounts of nitrogen of different categories added in monthly precipitation in Vellayani expressed as percentage of total nitrogen are presented in Table IV.

NH_3-N varied from 51.5 to 80.5 per cent with an average of 67.2 per cent. It is evident that the major portion of the total nitrogen added in rain in Vellayani is in the ammoniacal form. NO_3-N ranged from 18.5 to 48.0 per cent with a mean of 31.1 percent. It is also an important and sizeable fraction of total nitrogen. NO_2-N fluctuated between 0.4 and 3.1 per cent with an average value of 1.7 per cent. It is an insignificant fraction and is obviously of little consequence.

From the preceeding discussion it is quite evident that the accession of nitrogen in rain in Vellayani is of such magnitude that it must be reckoned with in drawing up the nitrogen balance sheet of the cultivated soils in this region. The annual addition of 10.543 kg nitrogen in a readily available form to every hectare of soil is undoubtedly a substantial contribution to the nitrogen economy of these soils being equivalent to the nitrogen supplied by 52.5 kg of commercial ammonium sulphate. As pointed out earlier, the rainfall received in Vellayani during the ! 2 months covered by the present investigation, viz., 1213·8 mm, is far below normal. As the average annual precipitation in this station is 1800 mm, it is reasonable to conclude that the acquisition of nilrogen by soils in Vellayani would in years of normal rainfall be higher than the present assessment

Obviously, the amount of nitrogen added to soils by rain is small compared to the annual losses of this major nutrient due to crop removal. It cannot, therefore, be considered as a substitute for the use of farm manure or commercial forms of nitrogen or growing of legumes in the maintenance of soil fertility. It is, however, clear from the results of the present study that nitrogen added in rainfall in Vellayani is of a magnitude that is of agronomic significance and may go a long way in replenishing the annual losses due to leaching, volatalization and erosion. Kerala is a region of heavy rainfall and the annual precipitation ranges from 1800 mm in the south to as much as 4000 mm in the north. As the quantity of nitrogen added by monsoon rains is largely dependent on the amount of precipitation, more investigations must be undertaken to evaluate the contribution that rain makes to the nitrogen supply of soils in important agricultural regions in this State.

Summary and **Conclusions.**

An attempt was made to assess the amount of nitrogen added to the soils of

Vellayani by monsoon rains. The study covered a period of one year, viz , September 1965 - August 1966, during which a rainfall of 1213.8 mm was recorded. Three forms of nitrogen were determined, viz , ammonia, nitrate and nitrite.

The concentration of NH_3-N far exceeded that of NO_3-N and NO_2-N in all the rains received. The month to month fluctuations were wide, being highest during the hottest months of the year. Light showers showed relatively greater concentration than heavy downpours. As the interval between two rains was longer the higher was the ammonia concentration. The concentration of NO_3-N was much greater than that of NO_2-N in rain in Vellayani. The monthly variation was narrow, indicating that nitrate was less influenced by season than ammonia. NO_2-N tended to be greater m rains arsociated ' with lightning. The concentration of NO_2-N was very low in all the rains in Vellayani.

1213.8 mm rainfall received in this station during the year added 10.543 kg total inorganic nitrogen/hectare, comprising 7.304 kg NH_3-N, 3.056 kg NO_3-N and 0.103 kg NO_2-N. This is a substantial contribution to the nitrogen economy of the soils of this region, being equivalent to the nitrogen supplied by 52·5 g ◦ commercial ammonium sulphate. As the precipitation in this station during the 12 months covered by this investigation is far below normal, it is reasonable to conclude that the acquisition of nitrogen by the soils of Vellayani from monsoon rains would in years of normal rainfall be higher than the present assessment.

Acknowledgement.

The data presented in this paper form part of a thesis submitted by one of the authors (K. B.) for the M. Sc. (Agri) Degree in Agricultural Chemistry of the University of Kerala. The authors are grateful to the University for permitting the publication of this paper.

The authors also wish to express their indebtedness to Dr. C. K N. Nair, Principal and Additional Director of Agriculture (Research), Agricultural College & Research Institute, Vellayani, for kindly providing necessary facilities for this work and for valuable advice in the planning and execution of this investigation.

References

1 American Public Health Association (1961) *Standard methods for the examination of water and sewage.*

2. Bamber, M. K. (1900; *Report on Ceylon Tea Soils, Colombo.*

3. Das, A. K., Sen, *G. C.* and Pal, C. K. (1933) The composition of rain water of Sylhet. *Indian Agr. Sci.* 3: 353-359.

4. Eriksson, E. (1952) Composition of atmospheric precipitation. *Tellus* 4: 215.

5. Harrison, J. B. (19i2) Composition of rain water. *Rpt. Exp. Agr. Rpt. Sci. and Agr.* 1940-10, 15-18.

6. Harrison, J. B. and Williams J. (1897) The proportion of chlorine and of nitrogen as nitric acid and as ammonia in certain tropical rain waters. *J. Amer. Chem. Soc.* 19: 1-9.

7. Juritz, C. F. (1914) Chemical composition of rain in the Union of South Africa. *South African J. Sc.* 1ft 170-179.

8. Koch, D. E. V. (1941) The nitrogen content of Ceylon rain. *Trop Agr.* (Ceylon) 97: 74-77.

9. Koch, D. V. E. (1943) The nitrogen content of Ceylon rain. *Trop. Agr.* (Ceylon) 99: 18-19.

10. Leather, J. W. (1906) Composition of Indian rain and dew. *Mem. Dep. Agr. India Chem. Ser.* 1: 1-11.

Meyer, J. and Pampfer, E. (1959) Nitrogen content of rain water collected in the humid central Congo basin. *Nature* 184: 717-718,

Miller, N. H. J. (1905) The amounts of nitrogen as ammonia and as nitric acid and chlorine in the rain watet collected at Rothamsted. *J. Agr. Sci.* 1: 280-303.

13. Rao, G., Gapala and Dhar, N. R. (1931) Bildung von Stickoffverbindungen in Luft und im Beden unter dem Einfluss des Lichtes. *Zeitschr. Anorg. Allgem. Chem.* 199: 422-426.

14. Tracy, S. M. (1895) Ammonia in rain water. *Miss, Agr. Exp Sta. 8th Ann, Rpt.* 102.

15. Trieschmann, J. E. (1919) Nitrogen and other compounds in rain and snow. *Chem. News.* 119 49.

16. Venema, K. C. W. (1961) *Potash Trop. Agri.* 4: 32.

17. Vijayalakshmi, K. and Pandalai, K. M. (1962) Nutrient enrichment of the coconut soils of the humid Kerala coast through monsoon precipitation. *Nature* 194: 112-113.

18. Vijayalakshmi, K. and Pandalai, K. M. (1963) On the major plant nutrient contents of rain water received in the humid Kerala coast *Indian Coconut J* 16. 4: 158-166.

19. Wilson, A. T. (1959) Surface of the ocean as a source of air borne nitrogenous material and other plant nutrients. *Nature* 184, 99-101.

20. Wilson, B. D. (1921) Nitrogen in the rain water of Ithaca, N. Y. *Soil Sc.* 11: 101-110.

21. Yaalon, D. H. (1964) The concentration of ammonia and nitrate in rain water over Israel in relation to environmental factors. *Tellus* 16: 200-204.