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Plant Nutrient Contribution by Rainfall in the Highly Industrialized and Polluted Patancheru Area in Andhra Pradesh

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Abstract: Rainwater contains nutrients and can, in a low-input situation, constitute an important nutrient source for crop production. During 1981-90, rainwater was collected using standardized collection procedures at three different locations at ICRISAT, Patancheru, Andhra Pradesh. Samples were analysed for N, P, K, S, Ca, Mg and Na. Ion concentrations were low and varied from year to year. The mean pH was 7.05. Because the locations were close to each other, there was no significant variation in the composition of rainwater among the locations. There were negative correlations between the amount of rainfall and the chemical parameters. Phosphorus was positively correlated with N, K, S, Ca, Mg and Na. Patancheru is highly industrialized and its atmosphere will have a bearing on the composition of rainwater. Sulphur fertilizer response experiments should not be carried out at this location. On an average, rainfall at this location contributes, per hectare, 5.8 kg N, 0.4 kg P, 4.8 kg S, 1.7 kg Ca, 1.7 kg Mg and 10.5 kg Na. The increase in N, P and S contribution was higher during 1986-90 than in 1981-85. (***Key words:*** *pH, nutrient elements, ion concentration, rainwater, rainfed agriculture, nutrient uptake, nutrient removal*)

Rainwater usually contains small but measurable concentrations of many elements derived either from dissolution of airborne particulate matter or from equilibration of rainwater with atmospheric gases (McGraw-Hill 1982). Rainwater could provide significant amounts of certain essential nutrients for agricultural crops and natural plant communities (Stevenson 1982). In the semi-arid tropics, summer storms produce high-intensity rains that are short in duration and limited in aerial extent (Osborn 1968). Long-duration storms travel considerable distances and are widespread. The different storm types and air mass originations suggest that important seasonal and spatial differences should exist in rainwater inputs of essential plant nutriets. Fewer data are available on the rainfall composition in the vicinity of ICRISAT-Patancheru in Andhra Pradesh. Patancheru is an industrial satellite town near Hyderabad with over 300 large and medium-scale pharmaceutical, heavy engineering, paint, paper and chemical factories. The industries of the area generate a cumulative 8×10^6 L d^{-1} of effluents that are directly discharged onto the surrounding land, irrigated fields, water bodies, *etc.* polluting the area (Shiva Kumar *et al.*,1997). Industrial emissions are important in nutrient cycling and plant growth due to their distance, availability and timing.

The objective of this study was to measure the plant nutrient input by rainfall on a long-term basis in a semi-arid climate and in an industrial zone.

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Materials and Methods

Rainwater samples were collected from June to December every year for 10 years (1981-1990) from three different locations on the ICRISAT-Patancheru Campus (IC): the Meteorological Laboratory (Met Lab), Alfisol watershed-1 (RWI) and Alfisol watershed-3 (RW3). They are approximately 2-3 km from one another. Standard Class 1 rain gauges with eye reading and self-recording equipment were used to collect samples after each rainfall event. Frequent wind storms in the semi-arid environment deposited particles from local sources and few samples were therefore discarded. The samples were stored at 4°C and were analysed for pH, N, P, K, S, Ca, Mg and Na contents, depending on the volume of the rainwater collected. A limited number of 3-4 samples from each year were analysed for urea-N.

The nutrient concentrations in each water sample were estimated as explained below:

pH was measured by the glass electrode method; N: inorganic-N was estimated by steam distillation using magnesium oxide and Devarda's alloy (Black 1965); P: phosphate-P was estimated in a 20 mL aliquot using ammonium paramolybdate and ascorbic acid (Watanabe & Olsen 1965); K: was estimated using an atomic absorption spectrometer (APHA 1985); S: Sulphate-S was estimated turbidimetrically using barium chloride (APHA 1985); Ca, Mg and Na: were estimated using atomic absorption spectrometer (APHA 1985). These values were then extrapolated to the quantity of nutrients (kg ha^{-1}) available in rainwater over a hectare of land.

Nutrient (kg ha^{-1}) = Rainfall (cm) x concentration (mg L^{-1}) x 10^{-1}.

Analysis of variance was used to compare locations, years and location x year interactions.

Results and Discussion

Screening of the samples based on physical verification for wind-blown dust particles resulted in the removal of 3-4 samples per year. The percentage sum of squares of nutrients attributed to location difference was very small. Maximum percentage sum of squares of nutrients were found between years. This observation was true for all the nutrients analysed from ICRISAT rainfall data over a 10-year period. Table 1 gives the average nutrient composition of rainfall added to the soil each year at the three locations on ICRISAT-Patancheru Campus. There were negative correlations between the amount of rainfall and chemical parameters (Fig. 1). Strong correlations were observed between P and the other nutrients estimated. Likewise, significant positive correlations were

Table 1. Average nutrient composition of rainwater (mg L^{-1}) added to the soil at ICRISAT-Patancheru during 1981-90

Year	Rain (mm)	No.of events	N	P	K	S	Ca	Mg	Na
1981	672	27	0.39	0.05	*	0.39	*	*	*
1982	250	11	0.80	0.09	0.52	0.84	1.69	0.28	2.21
1983	784	36	0.65	0.05	0.46	0.84	1.30	0.49	2.03
1984	435	18	1.25	0.10	0.66	1.59	1.41	0.31	4.40
1985	265	15	0.57	0.04	0.69	0.84	1.90	0.40	1.82
1986	408	19	3.31	0.08	0.31	1.24	1.35	0.28	3.32
1987	577	25	1.57	0.14	0.61	1.42	2.24	0.30	3.32
1988	700	28	1.38	0.05	0.26	1.13	0.77	0.29	1.31
1989	795	29	1.49	0.08	0.47	0.20	0.76	0.29	1.31
1990	548	28	0.90	0.13	0.56	0.43	1.20	0.27	0.70
SE			0.11	0.01	0.10	0.05	0.17	0.03	0.23
CV			14.90	26.70	34.0	9.90	21.5	14.8	21.40

* Not analyzed

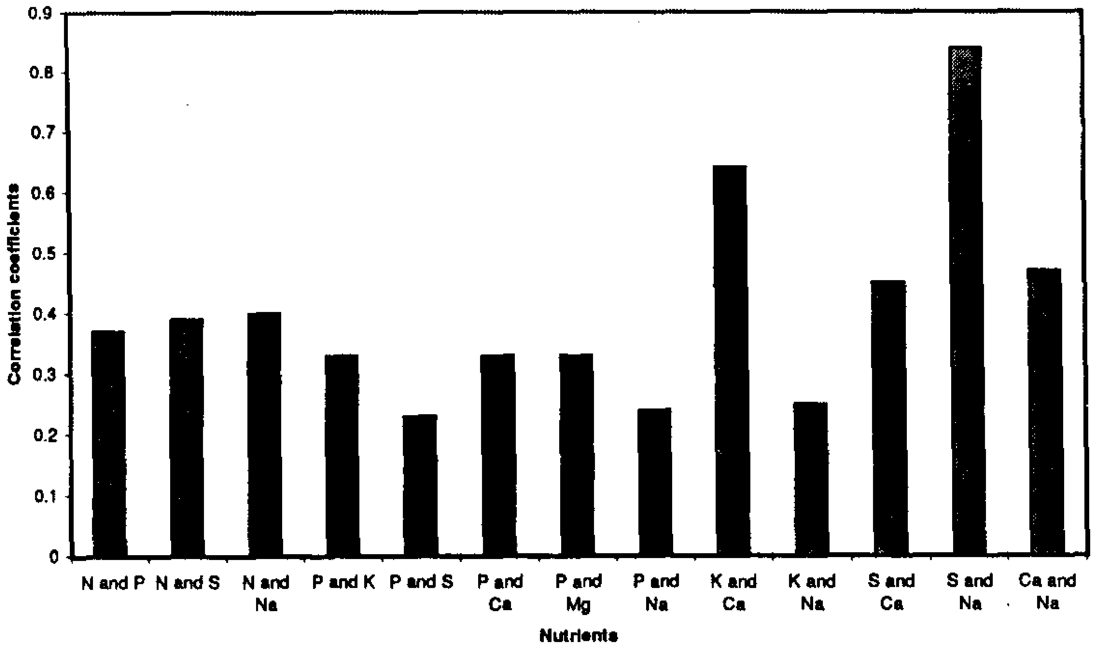

Fig. 1. Correlation coefficients for relationships among the concentrations of chemical constituents of rainwater

present between Ca and other nutrients, and between Na and other nutrients.

pH

Rainwater contains, in a dissolved state, each of the gases present in the lower atmosphere. Carbon dioxide is derived from both biological respiration and burning of fossil fuels, and reacts with rainwater to form carbonic acid.

The presence of free oxygen and carbon dioxide makes rainwater both a natural oxidizing agent and an acid. Rainwater equilibrated with atmosphere has a pH of 5.7 (McGraw Hill 1982). At ICRISAT, the pH of rainwater varied between 7.3 and 6.73 with a mean of 7.05. It may be due to enriched Ca and Mg. These ions may be buffering acidic deposition. All the three locations showed little variation with a CV less than 4 per cent (Table 2) for all the years. The trend is slowly towards acidic with the recording of pH 6.7 and 6.8 in the years 1989-90.

Nitrogen (N)

The amount of inorganic N contribution annually by rainwater ranged from 1.34 to 11.73 kg ha^{-1}. There was a very little variation in the concentration of inorganic N. The mean inorganic N concentration (1.23 mg L^{-1}) did not vary much from one location to another. No urea-N was detected in the selected number of rainwater samples analysed.

Table 2. Average pH of rainwater for three locations (RW1, RW3 and Meteorological Lab) at ICRISAT-Patancheru during 1981-90

	Met Lab	RW1	RW3	Mean (3 locations)
Mean	7.15	7.01	7.02	7.05
SD	0.26	0.20	0.20	0.19
CV	3.68	2.82	2.82	2.70

Total inorganic N contribution from rainwater was small compared to crop N requirements. But it is enough for natural plant communities to be able to offset N losses through leaching and denitrification (Stevenson 1982). However, in urban areas combustion emissions are believed to be the major source of nitrogen oxides (Robinson & Robbins 1970).

On an average, 5.8 kg ha^{-1} of N is contributed by rainwater. It is a significant contribution although we can expect fertilizer response to N. Also a slightly higher amount of mineral-N was contributed by rainwater in the years 1986-90 than in 1981-85 (Fig. 2).

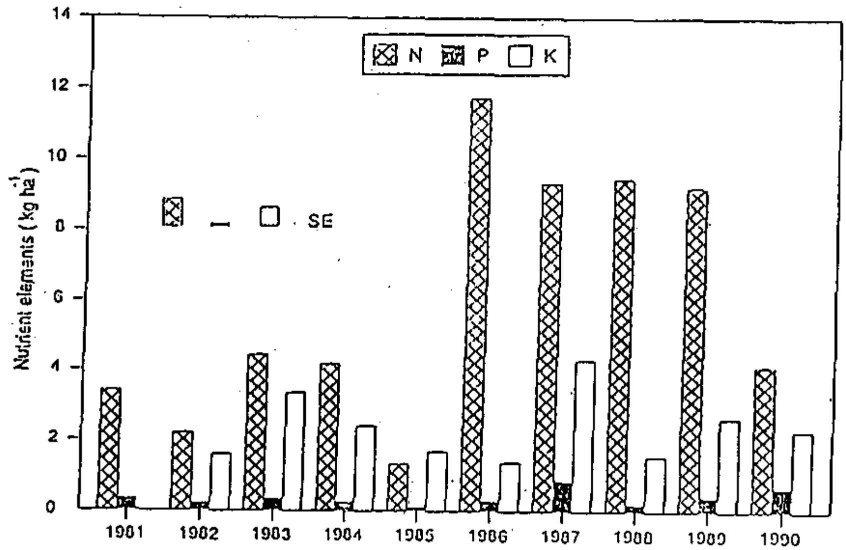

Fig. 2. Average values of N, P and K added to the soil at 3 locations (RW1, RW3 and Met. Lab) on ICRISAT Campus during 1981-90

Phosphorus (P)

On an average, 0.11 to 0.89 kg P ha^{-1} was added to the soil by the rainwater. There was a large variation in phosphate concentration with a mean value of 0.08 mg L^{-1} for 10 years. Positive correlations were present between phosphorus and other nutrients.

At ICRISAT, the amount of P added to the soil by rainwater was slightly higher (0.43 kg P ha^{-1}) at RW1 and RW3 locations, where wind-blown particulate matter was high, compared to the amount (0.32 kg P ha^{-1}) recorded at the Meterological laboratory. This is in agreement with the findings of Pierrou (1976) that sources of P are mainly terrestrial dust and sea spray. The average addition of about 0.5 kg P ha^{-1} by rainwater is small compared to plant P uptake, but it should play a good role in contributing P to the plant and crop in readily available form. Figure 2 shows that P contribution is higher in the period 1986-90 than in 1981-85.

Potassium (K)

Variation in K concentration was greater compared to that of the other cations (CV 34%). The amount of K contributed by rainwater ranged from 1.4 to 4.3 kg K ha^{-1} with a mean of 2.4 kg K ha^{-1}. The mean K concentration in rainwater was 0.5 mg L^{-1}. High positive correlation was observed between potassium and calcium. The mean addition of 2.36 kg K ha^{-1} by rainwater to soil was very significant, especially since it was entirely water soluble. There was a decreasing trend in K contribution in the period 1986-90 compared to 1981-85 (Fig. 2).

Sulphur (S)

The amount of sulphate-S deposited ranged between 1.53 kg S ha^{-1} in 1989 and 9.72 kg S ha^{-1} in 1987. There was a variation in the sulphate-S concentration over 10 years with a mean of 0.89 mg L^{-1}. The variation from location to location was small. A very high positive correlationship exists in the ion concentrations between sulphate-S and Na.

When a steel factory located near the ICRISAT-Patancheru Campus was closed during 1989, the sulphate concentration was very low (0.2 mg L^{-1}) showing that the steel industry plays a significant part in increasing the S concentration in the atmosphere. This is in conformity with the findings of Coleman (1966) that over land, sources of S emissions are heating, power production and industry. On an average, 5 kg S ha^{-1} was contributed by rainfall. A significant proportion of crop S requirement is met by rainwater, and farmers can save substantial costs on S fertilizers. There was an increase of S in rainwater in 1986-90 compared to the 1981-85 levels (Fig. 3).

The mean concentration of Mg ions in rainwater was 0.32 mg L^{-1}. As with the other nutrient elements, there was no variation among locations. Calcium and Mg inputs in rainwater decreased during 1986-90, compared to 1982-85 (Fig. 3). This may be due to widespread and long duration rainfall events. Annual variations in the ion concentrations of Ca and Mg may be attributed to the reaction of rainwater with the land-derived dust particles (McGraw-Hill 1982; Andraski & Bundy 1990).

Sodium (Na)

Average Na deposition varied from 1.44 to 24.8 kg ha^{-1}. The mean concentration of Na in rain-

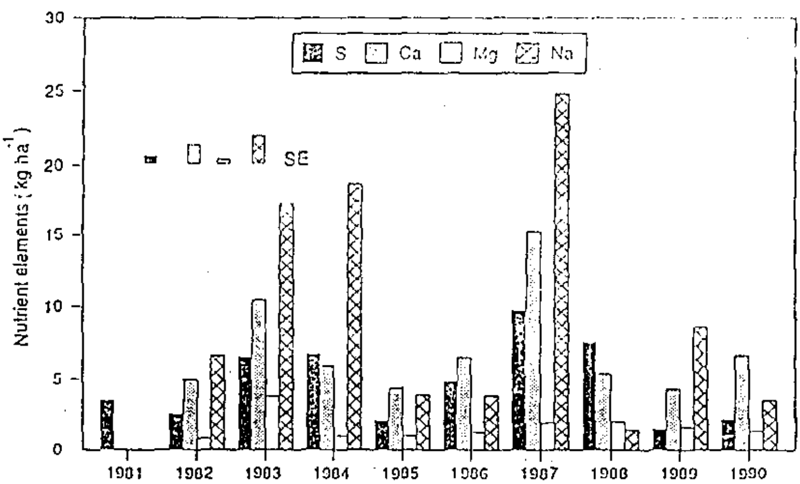

Fig. 3. Average values of S, Ca, Mg and Na added to the soil at 3 locations (RW1, RW3 and Met. Lab) on ICRISAT Campus during 1981-90

Calcium (Ca)

The average annual Ca contribution by rainwater at the three locations varied between 4.37 and 15.29 kg ha^{-1}. The mean concentration of Ca in rainwater was 1.40 mg L^{-1}. There was no significant variation from one location to another.

The mean contribution of around 7.1 kg Ca ha^{-1} by rainfall was significant. It takes care of 50 per cent of the requirement of cereal crops.

Magnesium (Mg)

Addition of Mg to the soil ranged between 0.86 and 3.83 kg ha^{-1} with a mean of 1.67 kg ha^{-1}.

water was 1.87 mg L^{-1}. There was very little variation among locations. Sodium concentration was very low in 1988 and 1990. Large variations may be attributed to the rains formed over the continental area which contain significant dissolved Na because of the reaction with land-derived dust particles (McGraw-Hill 1982). Sodium input through rainwater decreased in the years 1986-90 compared to 1981-85. The mean contribution of 10.5 kg of Na by rainwater to the soil may be important in certain situations.

With a mean annual addition of 6 kg of N, 1 kg of P_2O_5 and 2.5 kg of K_2O by rainwater to the soil, the farmer is economically benefitted indirectly by way of reduced fertilizer cost. The mean pH of rainwater was 7.05. Enriched Ca and Mg contents may have buffered the acidic deposition of rainwater. Because the locations were close to each other, there was no significant variation in the composition of rainwater among the locations. Ion concentrations were low and varied from year to year. Patancheru is industrially very active and its atmosphere will have a bearing on the composition of rainwater. True composition of rainwater might come out if the rainwater samples are collected away from the industrial area and compared. On an average, the annual rainfall at ICRISAT replenished 5-7 per cent of N, P and K and over 20 per cent of S, Ca and Mg removed by sorghum (economic yield 2.5 t ha^{-1}), pigeonpea (economic yield 1.5 t ha^{-1}), and chickpea (economic yield 1.2 t ha^{-1}) (Tandon 1993). The contribution of N, P and S through rainwater increased from 1986 to 1990. The amount of Na, Ca, Mg and K decreased in 1986-90. The importance of readily available atmospheric nutrients to plant growth should not be underestimated. Nutrient accumulation in biomass is an important aspect of nutrient cycling. Studies in other environments have shown that the input of soluble N in rainfall is greater than that lost in surface run-off waters (Schuman & Burwell 1974). Experiments (especially S fertilizer experiments) in locations close to industry should be carefully planned and input of nutrients and pollutants into the ecosystem *via* rainwater need to be fully evaluated.

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