ing 30 ppm at maturity The copper content of leaves and stem was slightly higher for about first 30 days but remained at 13 ppm in stem, 12 ppm in leaves and 6 ppm in fruiting parts till maturity

The dwarf and compact cultivar 'PSH' on unit area basis removed appreciably less quantities of nitrogen, phosphorus, potash, calcium, magnessium, manganese and zinc except copper, with higher nitrogen efficiency.

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J G. BHATT
A R S. NATHAN
CENTRAL INSTITUTE FOR COTTON RESEARCH
REGIONAL STATION
COIMBATORE- 641003
INDIA

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A new method for tracing nitrate movement in soil*

Sumario. Se llevaron a cabo investigaciones de campo y de laboratorio para probar el ion tiocianato (SCN) como trazador para el ion nitrato (NO_3) en estudios de lixiviación Los resultados en los que se usó tiocianato fueron relacionados a aquellos en que se usó nitrato en estudios de lixiviación y percolación Además, el tiocianato podría ser usado en estudios de movimiento de agua y de evapotranspiración

Nitrate ion (NO^{3-}) itself, chloride (Cl^-) ion and others have been used to monitor nitrate leaching in soil. But these ions naturally reside in soil, which made estimate of leaching more difficult. The present study introduced the thiocyanate ion (SCN^-) as a tracer for nitrate in soil. Thiocyanate does not reside naturally in soil It can be easily removed from soil after application by water extraction and determined colorimetrically by the addition of a drop of ferric chloride.

Soil Column Tests.

The relative miscible displacement patterns of nitrate and thiocyanate were compared by adding a mixture of the two ions to the tops of columns of soil. The mixture was leached and equal volumes of effluent were collected. Thiocynate colour was developed by adding a drop of 0.5 N ferric chloride to 5 ml of effluent Nitrate was determined by the phenoldisulphonic acid method Wavelengths on spectrophotometer were set at 410 μm for nitrate determination and at 470 μm for thiocyanate determination.

Apart from the small amount of nitrate in soil and errors of measurement, the concentrations of nitrate and thiocyanate in successive volumes of effluent were

* The author is beholden to Professor W. V. Bartholomew. Visiting professor from North Carolina University, Raleigh U S A for his guidance during this study

similar. The results of a typical study are shown in Table 1 when the ions were applied at the top of a dry soil column

That thiocyanate was detected in the first effluents collected in column experiments shows that like nitrate (1), thiocyanate moves with water. In similar trials with horizontal soil columns applied thiocyanate was detected at the wetting fronts of sandy loam and fine sand soils. Water was moved along the soil column 52 cm long and 3 cm wide. Readings in absorbance after water extraction for samples collected at 4 cm intervals varied from 0.15 near point of thiocyanate application to 1.90 at the wetting front. The equivalent values for a fine sand column were 0.28 and 2.00.

Field Locations and Procedures

Two field sites at about 180 km apart were employed during the 1975 cropping season. One situated at Ibadan was on Alfisol of the Iwo series, and the other situated at Ikenne, was an Ultisol (oxic) of the Iju series. At the onset of the study both sites were planted to maize in the early season. During the late season beans were planted at Ibadan and cowpeas at Ikenne. The texture of the soil within the first 30 cm of the sites is a sandy loam, although it was coarser at Ibadan

In the movement studies given volumes (2 - 3 ml) of thiocyanate solution were placed at 10, 20 and 30 cm depths in the soil at weekly intervals at two sites selected at random in each field. Slow placement of thiocyanate was performed using 0.164 cm plastic pipettes that were left in the field to mark the points of entry. The initial mean points of distribution were somewhat below the points of entry, the distances below in each instance being related to the soil water contents at the time of injection.

Movement observation were made at the end of each week by opening a shallow pit adjacent to the injection sites. Small samples of soil were taken at and in sequence below and above the points of injection

Table 1.—Relative concentration of SCN and NO_3 in effluent solutions.

In successive 20 ml volumes of effluent	Relative absorbance	
	for SCN	for NO_3
1st	0.88	0.87
2nd	0.85	0.91
3rd	0.82	0.92
4th	0.73	0.74
5th	0.42	0.43
6th	0.30	0.28
7th	0.24	0.27
8th	0.22	0.21
9th	0.21	0.19

by using a 1.6 cm diameter cork to remove about 6 cc of soil. Soil samples were extracted with water and thiocyanate colour was developed.

Results and Discussion

At Ikenne there were 42 movements observations at each placement depth during a period of 21 weeks. At Ibadan site there were 48 movement observations for each depth of placement during a period of 24 weeks. At both field sites the differences in movement were not statistically significant among the three depths of placement.

The weekly measurement of distance of thiocyanate movement for each depth at each site were added, and the means for the two sites and the three depths were found. The distances of thiocyanate movement under seasonal crop production are shown in Table 2 for

Table 2.—Vertical movement of thiocyanate tracer at different situation and rainfall regimes

Location	Treatment	Period (1975)	Rainfall (cm)	Drainage* (cm) water	Vertical Movement (cm)
Ibadan	Maize	May to Aug	49.9	37.6	134.3
Ibadan	Beans	Sept to Nov	29.7	12.6	45.1
Ibadan	Bare fallow	Sept to Nov	29.7	18.3	65.5
Ikenne	Maize	May to Aug	46.4	16.3	96.0
Ikenne	Bare fallow	May to Aug	46.4	19.6	115.2
Ikenne	Cowpea	Oct to Dec	18.8	6.5	39.2

* Calculated by using respective field capacity (%).

the two field sites. The results could have been exaggerated since the depths of measurement did not embrace all of the root zone of the cereal crops which sometimes extend to 1 m (for maize). Evapotranspiration due to roots would certainly reduce leaching.

However the data shown agree with the few seasonal distances of downward movement of nitrate already in literature. It has been suggested that appreciable amount of nitrate could be leached below a depth of 120 cm in a cropping season in East Africa (4). Generally evidence in literature (6) indicates that under rainfall regimes 50 - 100 cm in the tropics nitrate nitrogen will be moved downward between 50 - 100 cm.

Regression of the weekly distance (Dcm) of thiocyanate movement on weekly rainfall (Rcm) was performed for each depth at the two field sites. On several occasions the rainfall data could not be accurately reconciled with the time periods for movement observation. In those instances biweekly values were employed in the regression analyses. The regression coefficients for 10, 20 and 30 cm depths at Ibadan were respectively 3.96, 3.33 and 2.54, while r (correlation coefficient) values were 0.87, 0.76 and 0.76. The equivalent r values for Ikenne were 0.91, 0.88 and 0.90. Bates and Tisdale (2) had recorded a correlation of 0.96 for rainfall and nitrate movement. The combined regression equations for Ibadan and Ikenne were respectively,

$$D = 3.39R - 5.73 \quad (r = 0.78)$$

$$D = 3.10R - 5.60 \quad (r = 0.89)$$

The above equation indicate a strong relationship between thiocyanate leaching and rainfall. It is shown that a 1 cm rainfall above threshold amount could move thiocyanate (as a tracer for nitrate) by 3 cm.

The threshold fainfall (when upward or zero thiocyanate movement was recorded) at Ibadan was averagely 1.69 cm/week. Upward or zero nitrate movement in soil would normally occur when evapotranspiration exceeds water supply at a point in soil. The mean weekly potential evaporation recorded at Ibadan (3) for the experimental periods in 1975 (9/5/75 to 24/10/75 and 5/5/75 to 29/9/75) were respectively 2.37 and 2.21 cm/week. Smith and Montgomery (5) provided monthly means for Ibadan covering a number of years. For the season of the experimental work, May through September, the weekly average was 2.59 cm. If the above figures are compared, it could be said logically that 75 per cent or more of water loss by evapotranspiration occurred from the 0-30 cm depth under cereal. Most of the roots of cultivated crop reside in the upper 10 - 20 cm horizon (1).

Apart from being a good tracer for nitrate, thiocyanate could be used also in evapotranspiration and water movement studies. It should be possible to distinguish and evaluate the root zone characteristics of different soils and climatic regions and of the several kinds of crop plants.

Summary

Positive field and laboratory investigations were carried out to test thiocyanate ion (SCN^-) as a tracer for nitrate ion (NO_3^-) in leaching studies. Results using thiocyanate were related to that using nitrate in leaching and percolation studies. Thiocyanate could in addition be used in water movement and evapotranspiration studies.

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S. O. OJENIYI*
DEPARTMENT OF AGRONOMY
UNIVERSITY OF IBADAN
NIGERIA

* Now Senior Research Officer at Cocoa Research Institute of Nigeria. P.M.B. 5244. Ibadan. Nigeria.

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