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Kenyan tea litter: A source of ice nuclei

By R. C. SCHNELL, *Cooperative Institute For Research in Environmental Sciences, University of Colorado, Boulder, Colorado, U.S.A. 80309, and NOAA, Air Resources Laboratories, Boulder, U.S.A.*, and SUAN NEO TAN-SCHNELL, *4251 Ponderosa Court, Boulder, Colorado 80301, U.S.A.*

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ABSTRACT

A strong source of relatively active ice nuclei has been identified within the surface litter layer of tea plantations around Kericho, Kenya. This area also has the earth's largest known hailfall frequency. Aerosols produced from the tea litter retain their ice nucleation activity.

1. Introduction

Hail falls an average of 132 days a year on to the tea estates in the Kericho area of Western Kenya–a possible world record (Alusa, 1976). These localized storms damage tea crops and, in many cases, are one of the largest single natural variables affecting tea production. Approximately 70% to 85% of all storms in this area (07 lat., 35° E. long.) produce hail reaching ground level (1800 to 2000 m ASL) (Alusa, 1976). The hail is, for the most part, less than 10 mm in diameter. At some early stage in the production of hail in these clouds embryonic ice crystals form and grow by the collection of super-cooled water vapor or water drops. Inorganic soil materials (Isono et al., 1959) have been suggested as possible sources of atmospheric ice nuclei (IN) from which the embryonic ice crystals would initiate. More recently, decomposition products of terrestrial vegetation have been found to be good IN with IN concentrations in the atmosphere, and in precipitation (rain and hail) observed to mirror the activity of the IN found in the local plant litter (Schnell and Vali, 1976). Rosinski et al. (1980) have observed that up to 50% of the ice nucleating particles collected in the outflow regions of Colorado thunderstorms were natural organic particles in the size range from 1 to 10 μm radius.

This note reports on a study of the availability and ice-forming power of IN in and around the Kericho tea-growing (and hail) areas. On three occasions between 1974 and 1978 samples of soils, plant litter, and plant leaves were collected in the tea estates near Kericho and at lower elevations (to 1000 m ASL) on a line west of Kericho to Lake Victoria (50 km) and east of Kericho to Nakuru (90 km). These samples were tested for IN (freezing nucleus) content within 1 to 4 weeks of collection in the manner described by Schnell and Vali (1976). Later, composite samples of the tea litter were dispersed into a large containment tent and the size distribution and IN activity of the tea aerosol monitored over time.

2. Results

In September 1974 tea litter was found to contain more active IN (some active at −5 °C) than plant litters collected in the adjacent indigenous Mau Forest or in litter from eucalyptus groves (planted to replace portions of the Mau Forest). Plant litters collected away from the Kericho area also contained fewer IN than the tea litters. In February 1977 and June 1978 the IN activity of the litters from the eucalyptus groves and Mau Forest was similar to that observed in

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1974, whereas the tea litters were slightly less active than in the previous period. In Fig. 1 may be seen the range of the tea, eucalyptus and Mau Forest litter IN activity measured in 1977 and 1978; the bracketed numerals indicate the number of separate sample areas represented.

In 1977 and 1978, samples of tea litter from the surface, and from 5 cm below the surface from five widely separated tea estates were tested for IN activity. Results showed that the surface of the litter layer contained far more active IN than did samples collected 5 cm lower in the litter layer; threshold IN temperatures were uniformly 3 °C to 5 °C warmer in the surface samples at the litter–air interface (where they would most easily be dispersed into the atmosphere). Vali et al. (1976) have documented the production of highly active IN under such favourable aerobic conditions of natural leaf decay such as those at the top of tea litter layers.

In tea litter aerosolization tests, 1.5 g samples of tea litter (produced by mixing 11 litters from 1977 and 1978) were single puff aerosolized into a 2.75 m^3 Mylar-coated aerosol tent and the aerosol distribution monitored with two PMS overlapping laser aerosol spectrometers measuring particle radii from 0.045 μm to 23.5 μm. Total suspended aerosol mass per unit volume of air sampled in the tent (averaged over a 5 min period) was determined by integrating under the $dV/d \log R$ curves assuming a density of 1 for the suspended tea litter. At intervals while the aerosols were settling in the tent, 200 l samples of the tent contents were filter sampled using 0.45 μm pore diameter Sartorious hydrophobic membrane filters, and the IN content of the captured particulates determined using a combination membrane filter-drop freezing technique (Schnell, 1979).

The IN spectra from one such set of tests are presented in Fig. 2 for a tea litter aerosol produced at 09.26 local time. At 09.51, 25 minutes after aerosolization of the tea leaf litter, the tent contained a nominal 801.7 μg m^{-3} of suspended litter concentrated in the 7 to 10 μm radius range

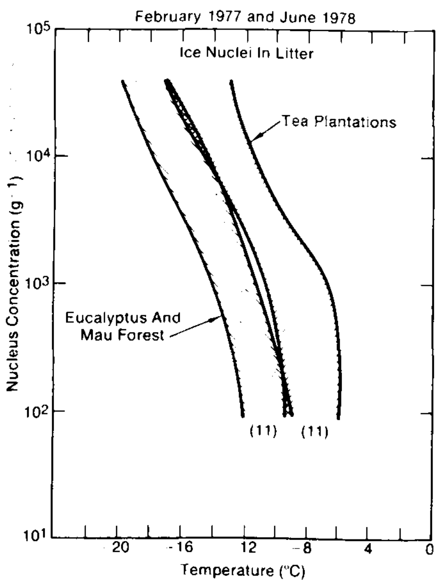

Fig. 1. Ranges of IN activity of litters collected in the Kericho, Kenya, area, February 1977 and June 1978. The IN spectra from the eucalyptus groves and Mau Forest are essentially the same and both have lesser IN activity relative to tea litters. Bracketed numerals indicate the number of separate samples contributing to each range. Spectra to the right of the graph represent the most active IN.

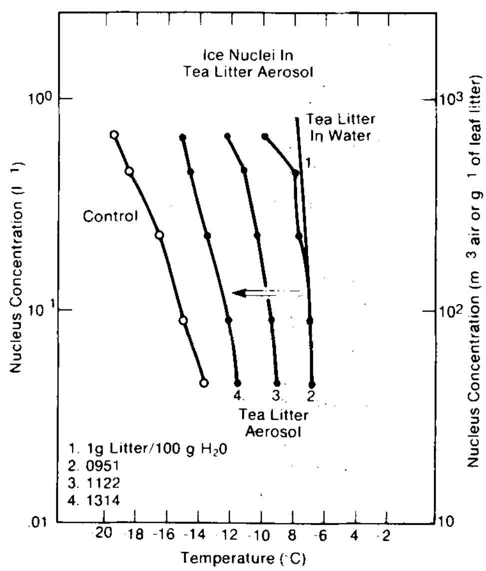

Fig. 2. Ice nucleus activity of bulk tea litter in water (1) and tea litter aerosols collected on filters (2–4). The control is obtained by measuring the IN on an unexposed filter. Spectra 2, 3 and 4 are from successive samples of a single charge of aerosol aging in a containment tent. Aerosol concentrations in the tent at the time of the respective IN spectra were: (2) 801.7 μg m^{-3}, (3) 71.8 μg m^{-3}, (4) 9.8 μg m^{-3}.

with IN activity as shown by IN spectrum 2, Fig. 2. It is interesting to note that the IN activity of the aerosol is nearly the same as that measured by adding 1 g of tea leaf litter directly into 100 g of distilled water (spectrum 1, Fig. 2). At 2 hours after aerosolization (11.27), particle concentrations in the tent had fallen to a nominal 71.8 $\mu g\ m^{-3}$ with IN activity as shown by spectrum 3, Fig. 2. At 3.5 hours after aerosolization (13.14), particle concentrations had fallen to 9.8 $\mu g\ m^{-3}$ with IN activity shown by spectrum 4, Fig. 2. Aerosol concentrations in the range of 50 to 100 $\mu g\ m^{-3}$ are normal in unpolluted rural atmospheres.

3. Discussion

Data presented in this report indicate that tea litter on the ground surface in the Kericho area contains relatively greater concentrations of active IN than other plant litters in the region, with the most active IN observed at the litter–air interface of the tea litter layer. Aerosols produced from the tea litter had a size distribution similar to that found in natural aerosols associated with thunderstorms (albeit on different continents) and maintained appreciable IN activity at aerosol mass loadings observed in natural atmospheres. Similar aerosolizations of plant litters into the Colorado State University isothermal cloud chamber have produced reliably repeatable IN concentrations over a wide range of cloud temperatures in direct proportion to the mass of leaf litter aerosolized (Schnell and Vali, 1976).

In a study of the cumulus clouds over the Kericho tea estates, Dye and Breed (1979) have shown that the clouds may be classified as continental, suggesting that the ice phase may be the predominant precipitation formation mechanism in these clouds. Alusa (1976) has shown that Kericho cumulus clouds and resultant hailstorms are characteristically triggered when surface level westerly winds from Lake Victoria flow up the Mau escarpment and converge with easterly winds over the higher ground near Kericho. The bases of these hail-producing clouds are typically between 500 to 1500 m AGL, somewhat lower than cloud bases of hail-producing clouds in Colorado, which are typically from 1500 to 2500 m AGL (Summers et al., 1979). Data presented by Rogers and Vali (1978) for Colorado cumulus clouds suggest that surface aerosol and nucleus measurements are representative of the inflow air at cloud base.

Thus, as an early step leading to the formation of hail in the Kericho cumulus clouds, we suggest that IN from the tea litter could be released to the atmosphere either naturally or assisted by the feet of hundreds of tea pickers going about their daily jobs. Once airborne, these small, light particles could be drawn aloft into the growing cumulus clouds to be involved, subsequently, in hail formation processes.

This scenario has a number of weaknesses, including the lack of data on IN activity and concentrations at cloud base. Also, it is not known what role atmospheric IN concentrations and aerosol size and number distributions play in hail formation (National Hail Research Experiment, Final Report, 1981). Probably, the major factors in producing the high hail incidence in the area are a combination of unique topographical influences and dynamic air flows conducive to hail formation. The prolific source of IN in the tea litter may be coincidental.

Some useful additional data on the role of tea litter aerosols in the formation of hail in the area should be forthcoming when planned measurements of the atmospheric IN concentrations and aerosol distributions above the Kericho tea litters, and at the bases of the hail-producing cumulus clouds, are undertaken. At that time it should also be possible to make some inferences as to why, if there are potentially as many active IN in the area as suggested by the above data, the local clouds are not fully glaciated, and thereby reduce the potential for hail formation of a size damaging to the tea.

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