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Rainfall and epizootic Rift Valley fever*

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Epizootic Rift Valley fever (RVF) has occurred in Kenya four times over the last 30 years. Widespread, frequent, and persistent rainfall has been a feature of these epizootic periods. A composite statistic, based upon measurements of these rainfall characteristics, is positive during periods of epizootic Rift Valley fever. The heavy rainfall raises the level of the water table in certain areas, flooding the grassland depressions (dambos) *that are the habitat of the immature forms of certain ground-pool-breeding mosquitos of the genus* Aedes. *RVF virus is probably transmitted transovarially in these species, very large numbers of which emerge under these damp conditions. This is when clinical signs of the disease are first seen.*

Rift Valley fever (RVF), a viral disease transmitted by mosquitos, has occurred in Kenya for about 50 years (*1, 3*). The disease appears as epizootics in domestic cattle and sheep, producing widespread abortions and causing deaths in young animals. The epizootics persist for 1-3 years, then often recur at 5–15-year intervals, and are always associated with periods of heavy rainfall in the generally dry, bushed and wooded grasslands where they occur (*1, 17, 18*). The relationship between rainfall and the RVF epizootics has not previously been analysed.

METHODS AND RESULTS

Records of RVF epizootics and of the rainfall at numerous stations in Kenya have been kept for many years. The rainfall records from 1950 to 1982 at five different sites in Kenya where epizootics of RVF occurred were analysed, but the correlation between the occurrence of RVF epizootics and rainfall in any one of these areas was frequently found to be low. For example, there were instances where no epizootic disease was recorded following periods of exceptionally heavy local rains. Similarly, at any one site during the epizootics the rainfall was sometimes similar to, or only slightly greater than, the annual mean value.

However, a composite statistic of the rainfall at five different sites, obtained as described below, correlates with the occurrence of RVF epizootics (Fig. 1). This statistic was calculated as follows: (*a*) the rainfall figure for each month from January 1950 to December 1982 was multiplied by the number of rainy days in the month, to produce a value weighted for the persistence of rainfall at each station; (*b*) the mean rainfall figure for each calendar month was calculated for each station for the 33-year period (396 months); (*c*) for each of these 396 values, the monthly mean was subtracted from the recorded value to give a surplus, which could be negative, relative to the value of the statistic for the month; (*d*) the mean of the surplus monthly rainfall multiplied by the number of rainy days was then calculated; (*e*) finally, the 12-month accumulated mean of this statistic was plotted in Fig. 1.

As shown in Fig. 1, the epizootics of 1951–53, 1961–63, 1967–68, and 1977–79 are clearly and consistently associated with periods of high, positive surplus rainfall. Only a few clinical cases of RVF were observed late in 1957 and 1982, correlating with the lower positive values of the composite statistic at these times, and no virus activity was recorded during periods of negative surplus rainfall.

DISCUSSION

The key factors in the association with virus activity appear to be widespread rainfall at several sites, resulting in a value greater than the annual mean, together with its persistence, as measured by the frequency and continuance of the rain over a long period. The apparent failure of heavy local rain to produce limited epizootics suggests, however, that some other factors are involved.

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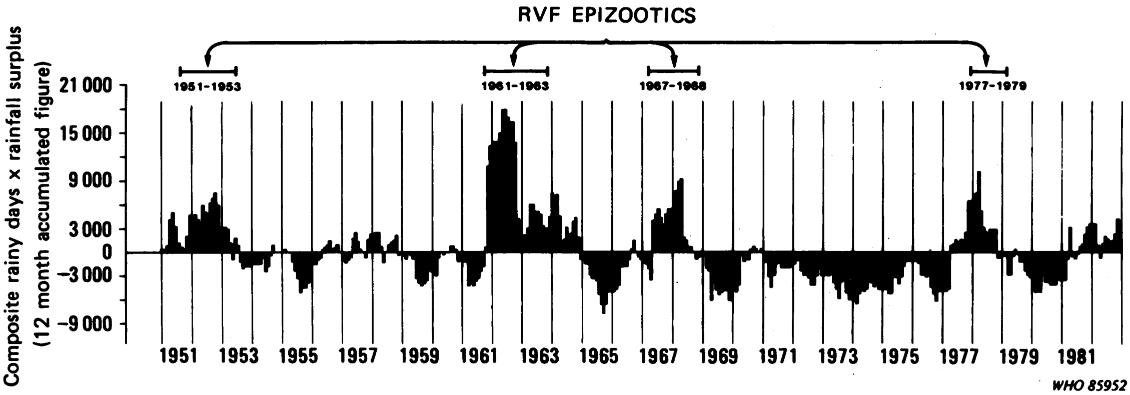

Fig. 1. The relationship between Rift Valley fever (RVF) epizootics and rainfall in Kenya for the years 1951–82. The graph depicts a composite statistic based upon number of rainy days and rainfall for each month at five sites in Kenya where RVF epizootics occur. The zero line represents the 33-year mean rainfall for each month. Values above the zero line represent periods of positive surplus rainfall.

Widespread rainfall in the region studied is caused by the changing characteristics of the intertropical convergence zone, the zone of confluence of air currents from north and south in the African continent that determines the extent and persistence of precipitation and cloud cover. The composite rainfall statistic in Fig. 1 is therefore a function of the activity of this zone. Continued cloud cover may be an important determinant for the survival of adult mosquitos, a key factor for the generation of mosquito-propagated virus epizootics (*19*). Convection and local air currents may be important vehicles for the transport of infected mosquitos or other vectors of RVF during epizootics (*15, 16*), and this could produce local or distant extension from the original foci of epizootics. It should be noted, for example, that the RVF outbreak in Egypt in 1977 was coincident with that in East Africa.

Rift Valley fever is probably maintained in interepizootic periods by transovarial transmission of the virus in mosquitos of the genus *Aedes* that breed in temporary ground pools (*dambos*). Periods of persistent rainfall raise the ground-water table to a level where the breeding sites of *Aedes* mosquitos become flooded (*8, 9*). This flooding requires heavy and prolonged rainfall. Flooding of the *dambo* formations induces the hatching of *Aedes* eggs and subsequent emergence of very large numbers of the adult mosquitos, which feed preferentially upon cattle (*10*). If these mosquitos are infected with RVF, virus amplification occurs in the vertebrate hosts, leading to further infection of other mosquito species that are capable of transmitting the virus (*11*). Many of these opportunist mosquito species colonize *dambos* in the grasslands (*2, 9*). The humid conditions and cloud cover present during the prolonged rainy periods allow a greater proportion of the adult *Aedes* population to survive through more feeding-oviposition cycles than in the hot, dry conditions usually prevailing in these areas.

It is interesting to note that the circumstances that allow the generation of epizootics of RVF in Kenya often prevail simultaneously throughout a large part of the African continent. Epizootics of RVF have therefore been recorded simultaneously in Kenya, the United Republic of Tanzania, and Zambia and often in the southern African countries (*2, 14, 20*).

This explanation of the mechanism of the effect of rainfall upon RVF therefore explains the patterns of RVF virus activity encountered in different parts of Africa. An annual emergence of infected *Aedes* mosquitos may occur in grassland areas with high annual rainfall (i.e., Zambia) or in the tropical forest belt that traverses much of the continent, and this is corroborated by serological studies of human and ruminant populations in riverine and forest-edge settlements in such areas (*2, 5, 6, 12, 13*). Emergence of some RVF-infected *Aedes* mosquitos may be expected to occur at 2–4-year intervals, coinciding with the excessive rainfall that floods *dambo* breeding sites in the bushed and wooded savanna (with moderately high rainfall) that is contiguous with the forest belt. Such areas are found in many parts of Africa in the high plateau area east and south of the tropical forest. Epizootics of RVF generally occur at 5–15-year intervals in the lower-rainfall areas of East and

South Africa, where cycles of drought are followed by periods of excessive rainfall. This is the situation throughout much of the Kenyan epizootic areas. A similar sequence may follow in the low-rainfall savanna areas that receive much less frequent periods of exceptionally heavy rain at 15–30-year intervals. In accord with this, foci of RVF have been identified in such areas (*4, 7, 16*).

Studies are currently being carried out to correlate the rainfall data with information obtained from satellite imagery (Meteosat, Landsat, and NOAA) on intertropical convergence zone activity and movement. In this way it may ultimately be possible to predict when RVF epizootics are likely to occur.

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RÉSUMÉ

PRÉCIPITATIONS ET FIÈVRE DE LA VALLÉE DU RIFT

Il y a eu au Kenya, au cours des 30 dernières années, quatre épizooties de fièvre de la vallée du Rift. Les précipitations sur l'ensemble du pays ont été enregistrées durant cette période et des zones étendues de pluie persistante ont été associées aux poussées épizootiques.

Il existe une bonne corrélation entre la valeur d'une statistique composite dérivée des chiffres de précipitations et chacune de ces épizooties. Cette statistique est une fonction des précipitations fortes et persistantes et du nombre de jours de pluie pendant cette période. Au Kenya comme dans la plus grande partie de l'Afrique, ces conditions climatiques sont le résultat des variations de la convergence intertropicale. Les conditions qui favorisent les épizooties de fièvre de la vallée du Rift peuvent donc apparaître simultanément dans différents pays de la région ainsi qu'on l'a observé en plusieurs occasions.

Dans les régions d'épizootie, les pluies entraînent une remontée de la nappe phréatique suffisante pour inonder les dépressions des herbages (*dambos*), qui sont des gîtes larvaires reconnus pour certains *Aedes*. Il y a émergence de fortes populations d'*Aedes* après les inondations et ce phénomène coïncide avec les premières manifestations cliniques de la maladie. Les moustiques du genre *Aedes* transmettent le virus de la fièvre de la vallée du Rift par voie transovarienne, ce qui explique probablement la persistance du virus entre les épizooties.

REFERENCES

1. Daubney, R. et al. *Journal of pathology and bacteriology*, **34**: 545 (1931).
2. Davies, F. G. *Journal of hygiene*, **75**: 219 (1975).
3. Davies, F. G. & Highton, R. B. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **74**: 815 (1980).
4. Davies, F. G. et al. *Journal of hygiene* (in press).
5. Digoutte, J. P. et al. *Annales de microbiologie*, **125 B**: 107 (1974).
6. Henderson, B. E. et al. *Annals of tropical medicine and parasitology*, **66**: 343 (1972).
7. Fagbami, A. H. et al. *Nigerian veterinary journal*, **2**: 45 (1973).
8. Linthicum, K. J. et al. *Mosquito news*, **43**: 464 (1983).
9. Linthicum, K. J. et al. *Mosquito news*, **44**: 228 (1984).
10. Linthicum, K. J. et al. *Journal of the American Mosquito Control Association*, **1**: 93 (1985).
11. McIntosh, B. M. *Journal of the South African Veterinary Association*, **43**: 391 (1972).
12. Maurice, Y. & Provost, A. *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, **22**: 197 (1969).
13. Metselaar, D. et al. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **68**: 114 (1974).
14. Office International des Epizooties, *Statistiques*. Paris.
15. Scott, G. R. et al. *Bulletin of epizootic diseases of Africa*, **4**: 17 (1956).
16. Scott, G. R. et al. *Journal of pathology and bacteriology*, **86**: 229 (1963).
17. Scott, T. W. et al. *Journal of medical entomology*, **20**: 625 (1983).
18. Sellers, R. F. *Journal of hygiene*, **85**: 65 (1980).
19. Sellers, R. F. et al. *Veterinary record*, **110**: 73 (1982).
20. Swanepoel, R. *Contributions to epidemiology and biostatistics*, **3**: 83 (1981).