Insect Transmission of Spike Disease of Sandal (*Santalum album*, Linn.).

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THE infectious character of Spike Disease having been experimentally demonstrated in a number of ways,[1,2,3,4,5] the next logical step in the investigation was to elucidate the mode of its dissemination under natural conditions. Strong circumstantial evidence, observations of previous investigators and the experience of other related diseases, led to the suspicion that the disease is possibly carried by a specific vector, the nature of which was still obscure.

Platform experiments[6] carried out since 1931 showed that the activity of the vector is confined to certain seasons of the year and that it operates above ground. Further confirmation of this fact was obtained from the natural infections which occurred among the potted sandal plants kept distributed in a heavily spiked area. The caging experiments[6] carried out in the 6-acre regeneration plot at Jawlagiri and later at Nognoor, demonstrated that the vector was effectively screened off by muslin cloth or by wire gauze of 10 to 20 meshes to the inch. The fact that the percentage of disease incidence in a given area was roughly proportional to the intensity of the infliction of scars pointed to the existence of scar-producing agencies which were also possibly responsible for the transmission of the virus. Continued observations showed that 64 per cent. of the scar-bearing plants got spiked while an incidence of only 8 per cent. could be recorded among the control plants which had not received similar injuries.

At this stage of the investigation, the Imperial Forest Entomologist, Dehra Dun, was invited to take up the problem from the entomological point of view. The extensive survey of the insect fauna associated with spiked and healthy areas carried out by Chatterjee,[7] led to the incrimination of a number of groups and individuals as vectors of Spike Disease. A series of carefully designed transmission experiments with these insects was conducted and a "mass infection cage" also was constructed into which were released the insect fauna from heavily spiked areas. Healthy and spiked sandal plants in pots were kept in the cage, so that together with the insect fauna the cage represented a "miniature sandal forest".

The above studies have resulted in the accumulation of mass of useful information and, from an entomologist's point of view, present a unique and very valuable contribution to the forest Entomology of South India. But from the point of view of the problem of insect transmission of spike, the efforts did not lead to any positive results.

A careful study of the experimental technique employed in the above series of studies showed that (1) the insects for the mass infection cage were collected and brought from areas located 50 miles away from Bangalore where the mass infection cage was situated, a circumstance which might have contributed towards the negative results; (2) Dover and Appanna[8,9] state "with the insect fauna we were no more fortunate. In October 1932, we reported a population of twenty thousand and hoped that we should be able to increase it to more than a hundred thousand. But in spite of every effort, the population fluctuated in the vicinity of twenty thousand and it was confined to a very small number of species, though at least two hundred thousand insects representing practically every species taken on sandal in the forest of North Salem, were introduced between June 1932 and March 1933"; (3) The insect fauna released into the mass infection cage mainly consisted of collections made during the day and "en masse" experiments with night fauna were not carried out. Careful and extensive observations had revealed that the scars are inflicted in large numbers during the nights[6] and this fact emphasised the importance of experimenting with the nocturnal insect fauna.

The problem of insect transmission was again taken up in May 1934 and several modifications in the light of past experience were introduced in the experiments. One of the cages was put up right in the midst of a heavily spiked area at Jawlagiri so that the insects could be released into the cage

soon after collection in a "nascent condition". The Denkanikota cage was situated 4 miles away from the centre of insect collections. The insect fauna for the cages were collected from spiked areas—both from sandal and associated host plants—during the night from 9–30 P.M. to 5 A.M. Other experimental details relating to the cages are given in Table I.

TABLE I.

	Denkanikota	Jawlagiri
Dimensions of the cage ..	24′×12′×7′	25′×12′×7′
Mesh of wire gauze ..	20 to an inch.	20 to an inch.
Date of start	7–5–1934	19–8–1934
No. of sandal plants:		
Healthy	42	37
Spiked	24	35
Total number of types introduced into the cage from commencement to date of first spiking ..	190	252
Total number of insects ..	8,421	15,766
Virulence of disease in areas from which insects were collected ..	1	5

At the commencement of the experiments it was observed that the insects did not feed on the spiked plants while on the healthy they could be seen in large numbers. With a view to render the spiked plants more attractive to insect attack, a certain number of them were planted in steel drums ($4' \times 1\frac{3}{4}'$) sunk in the ground. A number of healthy plants also were similarly planted up in the cage. These plants put on a new flush after a few weeks. A fresh batch of 23 healthy and 10 newly spiked plants bearing plenty of spiked foliage were introduced into the cage on 9—12—1934 so that the insects were given every chance to feed on the spiked plants. At the kind suggestion of Mr. M. V. Laurie, Provincial Sylviculturist, Madras (now Imperial Sylviculturist to the Government of India), the cage was partitioned on 9—12—1934 by a collapsible cloth screen. The spiked plants occupied one half of the cage while the healthy plants were placed in the other half. This arrangement enabled a control of the insect fauna in the cage, which could be driven to one or the other half of the cage and induced to feed on spiked or healthy plants as desired.

On 19—1—1935, one of the healthy plants in the cage at Jawlagiri looked highly suspicious after about 5 months and in the course of the next fortnight, the plant exhibited the characteristic symptoms of spike. Material from this plant was taken on 19—2—1935 to Denkanikota and utilised for grafting 6 healthy plants, two of which developed the disease on 28—5—1935, thus confirming that the spike symptoms produced through the agency of insects were transmissible by grafting in just the same manner as the natural spike tissue is capable of transmitting the disease. The infectious character of the disease produced by insects, was thus established, and was therefore identical with the natural spike occurring in forests not only with regard to the morphological symptoms but also with respect to its transmissibility of infection through grafting.

On 8—3—35 two more plants belonging to the same series at Jawlagiri manifested the disease. At this stage it was considered desirable to defoliate a certain number of the plants still continuing healthy, with a view to force out the masked symptoms if any. Mr. W. G. Dyson, District Forest Officer, North Salem, kindly suggested that only 50 per cent. of the plants should be subjected to this experiment while the rest should be allowed to remain in the cage. 15 from the August and 13 from the December batches of healthy plants were accordingly removed from the cage on 9—3—1935, defoliated and were kept under observation at Denkanikota. These plants were immediately replaced by an equal number of healthy plants. About the middle of April 1935, 5 among the defoliated and 8 among the plants which continued to remain in the cage, all belonging to the earlier August series got spiked, bringing up the total number of spiked plants to 16 out of the 37 healthy plants introduced into the cage at the very commencement of the investigation.

It should be made clear that so far there has been no disease incidence among the other two batches of healthy plants introduced into the cage in December 1934 and March 1935.* These plants are being kept under observation. It is remarkable, there has been no incidence among the healthy plants in the Denkanikota cage. It will be seen from Table I that the insect fauna both as regards types and individuals is very low in the case of the Denkanikota cage and the virulence of the Denkanikota area from which the insects were collected for the mass

* Since the above was sent to the press, one plant in the Denkanikota cage has got spiked.

infection cage, is only one-fifth of the virulence characterising the corresponding area at Jawlagiri. In the case of the Denkanikota cage, the insect collections had to be transported over a distance of four miles and were not therefore in as "*nascent*" a condition as those of Jawlagiri. These are possibly the causes for the negative results obtained so far at Denkanikota.

The remarkably high percentage of successful transmissions (43·2%) obtained at Jawlagiri in the mass infection cage, constitute a fundamental advance in the problem of spike disease investigation. The experiments establish that (1) the disease is insect-borne, (2) the insect-vectors occur during the nights, (3) that the vector responsible for disease transmission belongs to one of the 265 types introduced into the cage. On the basis of the frequency of occurrence, seasonal and regional distribution, numerical strength, their morphological characteristics and their reputation as vectors of allied diseases, a large number of groups and individuals have been eliminated, and the scope of our transmission studies with individual species has accordingly been restricted for the present, to three types of *pentatomidæ*, two of *jassidæ* and three of *fulgoridæ*. Transmission studies with these eight insects are now in progress.

Our best thanks are due to Mr. Dyson, D.F.O., North Salem, for his keen interest, constant encouragement and helpful criticisms during the entire course of these investigations, and to Mr. M. V. Laurie, Provincial Sylviculturist, for his many constructive suggestions. Our grateful thanks are also due to Sir C. V. Raman, KT., F.R.S., N.L., and Dr. V. Subrahmanyan for their kind and continued interest in the investigation.

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The Science of Rubber.*

AMONG the natural products which have influenced the progress of modern civilization, rubber occupies a pre-eminent position. The discovery of vulcanisation in the middle of the last century marks the beginning of its technological development while the advent of the pneumatic tyre, the increasing employment of power vehicles and the air craft paved the way for the utilisation of rubber on a gigantic scale. The special and exclusive properties of this raw material, more particularly, its elasticity, high impermeability to gases and liquids, resistance to shock and sound, electrical insulation and a marked resistance to chemical attack, properties which characterise no other single individual material of construction, have been exploited to the fullest advantage by technologists and in this endeavour, they have been assisted by an army of investigators who have contributed to the fundamental aspects of the science of rubber which constitutes the main thesis of the book under review.

The author who was entrusted with the responsible task of solving the problem of war time rubber emergency in Germany had a very enviable opportunity of enriching his experience and this fortunate circumstance has secured for the volume a prestige and authority which none will grudge. The diffcult situation was successfully met by the author and his colleagues whose strenuous efforts in perfecting the process are still being continued. The personal touch of the author is refreshingly perceivable as one goes through the pages of the book.

In this short review it is not possible to do justice by referring to all the excellent aspects of this book, but it is sufficient if attention is called to a few of the most notable features of this volume and indicate the comprehensive and thorough manner in which the subject has been approached. Such a fine production has been made possible through the combined efforts of

* *The Science of Rubber*, edited by Prof. Dipl.-Ing. K. Memmler. Authorised English Translation Edited by R. F. Dunbrook and V. N. Morris. (Reinhold Publishing Corporation, New York, 1934.) $ 15.00.