

On the basis of the observations given above in connection with those reported in the previous publications upon the reaction of plant cells to acenaphthene particles one can make the following inferences:—

1. Acenaphthene induces swelling of the plant organs but at the same time a slow development in length. This obviously results from the enlargement of the cell volumes due (a) to chromosome duplications, (b) to a simple cell expansion, and (c) to suppression of the cell division.

2. Acenaphthene particles act upon the dividing cells during the mitosis and meiosis in a specific way which is expressed in an absence of equatorial arrangements of the chromosomes and an absence of regular spindles.

3. The chromosomes divide but do not separate; thus duplication of chromosomes takes place. Sometimes (especially during the meiosis) the chromosomes get abnormally spread into the cytoplasm. This phenomenon leads to polynucleation and further to formation of polyads during the meiosis. Consequently acenaphthene might induce polyploidy and heteroploidy. Pollen developed from polyads are usually unviable.

4. Acenaphthene does not induce chromosome rearrangements of the type X-rays

do induce, or if it does, they are so insignificant that I have not been able yet to detect them.

5. The appearance of the expected numbers of bivalent chromosomes during the meiosis suggests that acenaphthene does not prevent chromosome pairing. Special experiments are required, however, for studying the question: 'does acenaphthene reduce synapsis?'

6. Acenaphthene interferes with the normal growth of the pollen-tubes, inducing swellings at the growing ends.

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Medical and Veterinary Importance of Fleas and Ticks and the Possibilities of their Control.*

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FLEAS and ticks are external parasites of great economic importance on account of their blood-sucking habit. They transmit numerous diseases to man and domesticated animals, and are also harmful to them in other ways. They have thus a direct bearing on medicine and veterinary science, and an indirect bearing on agriculture through affecting the efficiency of work in man and his live-stock by lowering their vitality.

(A) FLEAS.

Fleas affect man and domestic animals in two ways: firstly, as vectors of diseases

and secondly, as blood-suckers and annoyers of man and domestic animals.

The chief interest of fleas centres round their connection with the bubonic plague due to *Bacillus pestis*, which is primarily a disease of rodents from which it is transmitted to man by fleas. This disease has played havoc with man from times immemorial and is caused largely, if not exclusively, through the agency of fleas. In India alone upwards of 7,000,000 deaths, due to this disease, have occurred between the years 1896 and 1911. The disease is transmitted by the bite of an infected flea in which the regurgitation of blood due to the obstruction of the proventriculus introduces the plague bacilli in the body of the host. The proventriculus is blocked by the rapidly multiplying plague bacilli which

* Remarks in a discussion of the Sections of Zoology, Medical Research, Veterinary Research, Entomology and Agriculture in the Silver Jubilee Session of the Indian Science Congress Association, Calcutta, 1938.

enter the interstices of its spinous processes and thus the blood cannot enter the stomach of the flea. This obstruction proves fatal not only to the host but also to the flea. So plague is as much a disease of the flea as it is of rodents and man. This obstruction occurs more readily in some species like *Xenopsylla cheopis* the most efficient vector of plague bacilli, but it does not occur according to Hirst (1926, p. 198), in *X. astia* the inefficient transmitter of plague.

Fleas are suspected vector of *Kala-azar*, though competent opinion is still divided. *X. cheopis* according to Nicolle and Sparrow (1935) can transmit the causative agent of Tsutsugamushi fever under experimental conditions. Fleas can also transmit Rickettsial diseases in man. *X. cheopis* and other fleas have been incriminated as vectors of different kinds of typhus fevers in different countries. Hæmorrhagic septicæmia, a fatal disease due to *Pasteurella bovisseptica* in cattle, is transmitted according to Daubney, Hudson and Roberts (1934) in tropical countries by *Ctenocephalides felis*. Fleas belonging to the species *C. canis* act as the intermediate host of the tapeworm belonging to the species *Dipylidium caninum* which is found in dog and occasionally in man. The tapeworm gains entrance to a new host by being swallowed with crushed or living flea.

Besides the transmission of diseases, fleas are troublesome parasites. In many cases they are said to have rendered houses or other places uninhabitable for a time. The Sticktight flea (*Echidnophaga gallinacea*) is responsible in tropics and certain parts of the United States of America for a considerable annual loss to poultry breeders. The young chicken when heavily infested often die quickly but older fowls are more resistant. The fleas materially reduce the egg-laying capacity and check the growth of fowls. The Chigoe (*Tunga penetrans*) causes painful sores in man or even crippling if neglected. During the Great War (Jolly, 1926) in the East Africa the British Army had to wait for two days to occupy a position of great advantage vacated by the Germans, on account of its being infested with fleas of this species.

Fleas afford us a good instance that a mere systematic study of a group sometimes helps to clear up certain points of great economic importance. The Indian Plague Commissioners failed to understand the

reason why certain large areas had severe plague while others having similar ecological conditions were comparatively immune from it. The reason was found out by Hirst, who submitted a collection of fleas from two plague-free cities of Madras and Colombo to the Late Hon'ble N. C. Rothschild who determined the fleas to be different from *X. cheopis*—the most efficient vector of the plague bacilli—and they belonged to a new species *X. astia* which later on was experimentally proved to be a relatively inefficient vector of the plague bacilli. It was subsequently found out by some workers that in the plague-free places rats are infested mostly with *X. astia* and in areas infected with plague *X. cheopis* predominated. Thus a much despised systematic entomologist was instrumental in solving the problem of a great economic importance, which the trained applied entomologists with enormous funds at their disposal could not do within a period of seven years.

A fairly large amount of work on the ecology of fleas has been done. The effects of different kinds of food and different temperatures and humidity on the growth of fleas and their earlier stages has been ascertained in some cases. A technique for rearing and maintaining large stocks of fleas for experimental purposes has been devised by Leeson (1932, b). By following his methods the present author was able to maintain a stock of fleas at Cambridge larger in number than the human population of Cambridge for about two years. The work of Bacot (1914), Bacot and Ridewood (1914), Strickland (1914), Hirst (1926), Leeson (1932, a), Mellanby (1933), Sikes (1930, 1931), Buxton (1931) and Sharif (1937) on the effect of temperature, humidity and food on the increase and decrease of the population of fleas deserves to be mentioned.

It has been found that in most species the temperature of about 23° C. and 80 to 90 per cent. relative humidity are most suitable for successful breeding of fleas. High relative humidity is an essential condition for the growth of the larvæ of fleas, but not so much for the adult. Sikes (1931) proved experimentally that different kinds of food of flea larvæ have different hygroscopic properties and the optimum atmospheric humidity differed according to the kind of food employed so as to give the optimum water-content of the food. Rainfall

and high relative humidity of 70-90 per cent. have much to do with flea breeding. As a rule rainy months in summer are responsible for outbreaks of fleas, and extremely hot and dry weather retards their breeding.

Bacot (1914) showed experimentally that the larvæ of many species of fleas require blood in their food and will not grow without it. In nature it is supplied by adult fleas, which swallow more blood than they can digest, so that some of it is discharged along with fæces as scarcely digested blood. Sharif (1937) has experimentally proved that blood, although the most important part of the nutritional requirements of flea larvæ, is by itself not sufficient for their normal and successful growth. The flea larvæ require an additional food which in nature is supplied by the organic refuse present in the bed of the host of the adult fleas. He has further proved experimentally that flea larvæ require blood for their development in order to obtain the necessary supply of iron for their growth.

The effect of the above-mentioned ecological factors on the increase and decrease of the population of fleas is established. If those who are engaged on the work of prevention of diseases transmitted by fleas will take advantage of the researches of the above-mentioned workers, they will be able to understand the flea problem, and thus partially, if not exclusively, save the human race from its depredations. Fleas breed mostly in dust containing organic material protected from wind, rain and sun, but at the same time supplied with moisture due to urine and fæces of their hosts. If breeding places of fleas, which are mostly the resting places of their hosts, are carefully cleaned up, the premises will be cleared of fleas even though no attention is paid to the fleas on the hosts themselves. The location of breeding places of fleas is essential for their control. Future researches should be concentrated on studying and understanding the ecological factors governing the breeding places of different species of fleas. In flea-infested districts it is advisable to avoid the use of mattings and carpets as they afford facilities for their breeding.

(B) TICKS.

The importance of ticks as disease carriers in man and domesticated animals is well

known. They rank among man's worst enemies. There are probably none of the external parasites of domestic animals of more importance to the stock raiser in any country than the ticks, owing to the large number of diseases which they transmit from animal to animal. It is, therefore, safe to state that no more important problem than the eradication of cattle ticks confronts the farmers of any country.

The harmful effects caused by ticks to animals may be due to (a) tick-bite, (b) extraction of blood, (c) transmission of diseases and (d) tick toxæmia. It is obvious therefore that the owner of livestock cannot afford to ignore the presence of ticks on his animals if he wishes their efficiency to be maintained.

(a) *Tick-bite*.—It is a well-known fact that the bite of a tick causes ulcers or small wounds which may serve as points of ingress of bacterial infections. If the wounds caused by tick-bites are large the eggs may be laid by flies which develop into maggots and cause cutaneous myiasis. Ticks occurring on legs and between digits of feet in sheep and cattle give rise to sores resulting in lameness. The ticks also irritate the animals by their bites and they may die of "tick worry". *Argas persicus* and *Argas reflexus* may kill fowls or pigeons in a very short time if they attack in large numbers, quite apart from any disease they may convey.

(b) *Extraction of Blood*.—The extraction of blood by a large number of ticks makes the cattle so weak that they are depreciated in value from the commercial point of view. It makes them unfit for work and in milking animals the yield of milk is reduced to a considerable extent. The emaciated condition of the cattle is mainly due to the presence of a large number of ticks. Repeated attacks by large numbers of ticks shorten the life of animals, and make them weak so that they become an easy prey to other diseases. The massive tick-infestation even causes death of animals either due to excessive blood sucking or to tick worry. "In extreme cases, Mr. Mayer estimates that as many as 200 pounds of blood may be withdrawn from the host during a single season. This makes a gain in weight impossible even in the best of pastures" (*vide* Hunter and Hooker, 1907, p. 11).

(c) *Transmission of Diseases.*—The importance of ticks in general as vectors of various diseases of man and domestic animals continues to increase as our knowledge of them progresses. Smith and Kilborne (1893) made the first remarkable discovery of the possibility of transmission of protozoal parasites by Arthropod hosts by demonstrating the transmission of *Babesia bigemina* by *Boophilus annulatus*. This discovery by Smith and Kilborne opened up a vast field of research on the part played by Arthropods in the transmission of protozoal diseases, which has since then revolutionized our knowledge of tropical diseases. In man ticks transmit the causal agents of the relapsing fever (spirochætosis) all over the world, the Rickettsial diseases like tick-typhus fever, Marseilles fever and the Rocky Mountain spotted fever of America and Tularæmia. In domestic animals they transmit diseases caused by *Babesia*, *Theileria*, *Anaplasma*, *Spirochæta*, *Bacteria* and *Viruses*.

Piroplasmosis.—The term piroplasmosis is applied to diseases caused by *Babesia* and they are all transmitted by ticks. It includes some of the most dangerous diseases which affect domestic animals all over the world. Piroplasmosis occurs in cattle, sheep, horses and dogs. In many parts of the world it is impossible to import cattle for the reason that as many as 90 per cent. may die due to this disease. The Texa or tropical red-water fever of cattle due to *B. bigemina* is responsible for the annual loss of forty to hundred million dollars every year in the United States of America. In nature it is mainly transmitted by *Boophilus annulatus*, *B. australis* and *B. decoloratus*. The other dangerous diseases due to *Babesia* are the European red-water fever due to *B. bovis* which is transmitted by *Ixodes ricinus* and *Hæmaphysalis cinabarina* var. *punctata*, the biliary fever of horses due to *B. caballi* and *B. equi* which are transmitted by *Dermacentor reticulatus*, *Rhipicephalus evertsi* and *Hyalomma (Hyalomma) aegyptium*, and the malignant jaundice of dogs due to *B. canis* which is transmitted by *Rhipicephalus sanguineus* and *Hæmaphysalis leachi*.

Theileriosis.—One of the most formidable diseases of cattle in Africa due to *Theileria parva* is transmitted by some species of the genus *Rhipicephalus* of which *R. appendiculatus* is the most usual vector.

The mortality rate due to this disease is as high as 95 to 100 per cent. A benign type of theileriosis due to *T. mutans* is widely distributed in the warmer countries of the world. Infection due to this in adult cattle proves fatal in 5 to 10 per cent. cases only.

Anaplasmosis.—This disease due to *Anaplasma marginale* is very dangerous and has a fairly wide distribution. The death rate is 95 per cent. in adults and 50 per cent. in young ones. It has been experimentally transmitted by a large number of species of ticks.

Rickettsiosis.—Among the Rickettsial diseases the Rocky Mountain spotted fever, the tick-typhus fever and Marseilles fever in man and heart-water fever of cattle, sheep and goats are well known. The Rocky Mountain spotted fever which is due to *Dermacentrozeus rickettsi* is transmitted mostly by *Dermacentor andersoni*. Tick-typhus fever in India is probably transmitted by *Dermacentor auratus* and Marseilles fever whose causative agent is *Rickettsia conori* is common on the Mediterranean Coast and is transmitted by *Rhipicephalus sanguineus*. The heart-water fever due to *Rickettsia ruminantium* is common in South Africa and is transmitted by *Amblyomma hebraeum*, *Boophilus annulatus*, *B. australis*, and *Rhipicephalus capensis*.

Spirochætosis.—Some of the blood inhabiting spirochætetes are transmitted by ticks. *Ornithodoros savignyi* and *Ornithodoros moubata* transmit relapsing fever in man due to *Spirochæta duttoni*. The causal agent of the Central Asiatic and Persian relapsing fever in man is *Spirochæta persica* whose chief vector is *Ornithodoros papillipes*. *Ornithodoros turicata* has been definitely proved to be connected with the transmission of relapsing fever of man in the United States. Spirochætosis of domestic fowls which is due to *Spirochæta anserina* is transmitted by *Argas persicus* all over the world.

Bacterial Diseases.—Tularæmia or rabbit fever is a disease due to *Pasteurella tularensis*. It has been recorded from the United States and Japan and is primarily a disease of wild rodents but man is incidentally involved in it.

Virus Diseases.—Amongst the virus diseases the louping-ill (Macleod and Gordon, 1932) is transmitted by *Ixodes ricinus* in England, Scotland and Wales. This tick also transmits the causal agent of the "Tick-borne

fever of sheep" (Macleod and Gordon, 1933) in sheep, pigs and goats.

(d) *Tick Toxaemia*.—According to some observers the salivary secretion of ticks contains toxins and cases of tick paralysis in some animals and man are generally explained on the basis of their presence. Tick paralysis has been reported from the United States and Australia both in man and domestic animals. According to Regendanz and Reichenow (1931) the poison causing tick paralysis is specially formed in the female of *Rhipicephalus sanguineus* during the process of egg development. They experimentally showed that injections of eggs or ovaries of this tick just before oviposition gave rise in dogs to symptoms similar to those of tick paralysis.

The ecological studies on ticks have yielded useful results for their control. Unfavourable climatic conditions which are mainly responsible for keeping the number of ticks in check have been studied in some countries. In order that the work of extermination may be more intelligently and successfully carried out it is necessary that it should be based upon most accurate knowledge possible of the life-history, habits of the ticks and their natural enemies. Such work has been done extensively in the United States and some other countries. According to Nuttall (1913) wherever this type of work has been carried out intelligently great beneficial results have been obtained, and "large tracts of country in the United States, Australia and Africa" have "been rendered almost tick-free by these measures".

There is no doubt that ticks are comparatively free from the attacks of parasites and predaceous enemies on account of their passing a portion of their life concealed within the fur, feathers or scales of their hosts. Ticks have natural enemies both predaceous and parasitic. The study of their effects in limiting the increase of the population is being made at present in some countries.

The most efficient predaceous enemies of ticks are found among birds. The domestic fowls feed eagerly on ticks. Rats and mice feed upon ticks, and field mice assist in a limited way in destroying the engorged females. Toads, lizards and ants also feed on ticks.

Amongst the important parasitic enemies of ticks so far recorded are the Chalcids *Izodiphagus texanus* and *Hunterellus hookeri*. The former parasite has been during recent years introduced with some success on the eastern coast of the United States of America and in Montana for the purpose of controlling ticks. The amount of money spent upon this parasite by the United States Government only increases the importance of this type of work. Specially trained persons were asked from the Laboratory of Prof. E. Brumpt in Paris to help work in America. In 1928 Dr. R. A. Cooley undertook a tour in S. Africa in order to find out the parasites of ticks. A serious attempt by highly trained persons is being made at present at Montana, where a research laboratory costing about sixty thousand dollars was specially built for this purpose in 1927. According to Cooley (1932, p. 53) for the time being the use of tick parasites appears to afford the most promising method of control.

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