

PART VII.

SIGNIFICANCE OF SEX-DIFFERENTIATION AMONG LAC INSECTS.

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INTRODUCTION.

The well known fact that the adult female lac insect alone produces appreciable quantities of lac makes it highly important to be able to determine the ratio between male and female larvæ, (a) among different species of lac insects each growing on its best host-plant under similar climatic conditions, and (b) within the same race of insects during different seasons of the year.

The two main factors governing the development of the lac insect are nutrition and climate. Actual observation has shown, however, that the conditions favourable for the development in size or body of the full grown mother insect are not those which favour the formation of females in the next generation. From the beginning of the investigation the possibility was considered that sex formation occurs during the post-embryonic development, and may therefore be the result of differential nutrition of the young insects after fixation to the twigs and before metamorphosis has set in. It is known, for example, that in the case of ants and bees, the larvæ when well fed become 'queens', while if partially starved, they emerge as 'workers' or 'neuters.' Even here it has been shown that neuters are only sterile females, and starvation cannot actually determine the sex characters, although it certainly depresses their development and future function. In the case of lac insects, it was found that nutrition is without effect on the sex phase during the larval stage, but is of importance during the egg stage of existence. The larvæ, therefore, carry, as they are born, the sex characters with them and consequently the attempt has been made to determine the sex of the larvæ by external characters. With this object, lac insects were examined under a binocular microscope, at all stages of growth from the time of the larvæ just settling on a branch up to the occurrence of the first ecdysis, and it is claimed that with some practice it is possible to determine the sex-ratio among the larvæ of lac insects prior to any signs of moulting.

Sex-ratio in relation to moisture and the species of lac insect. Lac insects in Mysore.—There are two lac insects in Mysore. One is cultivated solely on *Shorea talura*, and has been named by the author *Lakshadia mysorensis*, being the Mysore lac insect; the other, most frequently found on *Ficus mysorensis*, has been distinguished as *Lakshadia communis*, as it is less restricted in its host-plant, and has been found all over South India, more or less in a wild state. The incrustation produced by the latter insect is, however, so meagre that it is not a commercial source of supply.

Lakshadia communis has two life cycles per year; in Bangalore one occupies some five months during the wet season, roughly from June to October, while the other takes seven months of the drier portion of the year from November to May. In June, 1918, a *Butea frondosa* tree was observed at Lingal (Mabubnagar District, Hyderabad State, Deccan) some of whose branches were covered with a characteristic thin incrustation of lac from *Lakshadia communis*. This proved on closer examination to be the product of winged males, during their second larval stage. Similar instances were afterwards noted on *Ficus mysorensis* in Bangalore, and in the city of Hyderabad on *Ficus bengalensis*. It was further found that the generation of larvæ which swarm at the end of the monsoons in Bangalore about early November give rise mainly to winged males, emerging during early March, while the generation of larvæ which are born from the dry season crop during the middle of May and June, give rise to more females than males, and the latter when emerging early in September are invariably wingless. A similar preponderance of males was observed in some brood-lac of *Lakshadia communis* growing on *Pithecalobium dulce* in Hyderabad in November 1920, kindly sent by the writer's brother, Mr. Khurshid Hassan. This was inoculated on to the same host-plant growing as a hedge in the grounds of the Indian Institute of Science, and again the emerging brood consisted almost entirely of winged males.

It should be noted, however, that at the end of the dry season, about May, some crown-shaped cells may be observed, probably parthenogenetic cells, and it is these which must be responsible for the continuation of the species. Like the fertilised cells, the parthenogenetic cells give rise to a greater proportion of female larvæ.

Thus the generations of larvæ, swarming from the longer and drier season (post- and pre-monsoon seasons) seem to be of critical importance, as they are able to maintain an increased rate of multiplication, while the one given by the monsoon-fed crop (June to October) gives rise to an excess of males, only a few normal and parthenogenetic cells being left to supply the brood.

It seems, therefore, to be the monsoon weather that induces the growth of the mother insect and increases its size, but the eggs that are being formed receive the male sex characters in a preponderating ratio. During the drier season the mother insect is smaller, but nevertheless these smaller individuals give rise to more females in the next generation. In fact, when eggs develop in the presence of moisture they receive the male sex characters, while in its absence the contrary occurs.

Difference in climate between two localities will therefore cause a difference in the sex ratio of the lac insects produced at a given season. Thus the relatively warmer and drier climate of Hyderabad during June and November tends to produce more females than the colder and more humid weather generally experienced at that time in Bangalore. If either season is exceptional, i.e., if Hyderabad is wet and Bangalore dry, the sex-ratio varies accordingly. Each of these two cases has been actually observed. Although under specially favourable conditions *Ficus* trees may be seen covered with long incrustations of lac, yet the quantity is rarely sufficient to make its collection commercially worth while, having regard to the uncertainty of the brood.

It has been observed with the brood of *Lakshadia communis* that food does not change the sex, the monsoon-fed crop always giving rise to winged males, irrespective of the different host-plants used to feed their larvæ.

A similar phenomenon of the variation of the sex-ratio with the season has been observed with *Lakshadia mysorensis*, the smallest but most prolific of lac insects, being the only trivoltine species known, with three life-cycles during thirteen months. The monsoon-fed crop is the heaviest in yield, occupying some four months for its growth, e.g., from June 16, 1922 to October 13, 1922. This season may be called wet, and with sufficient warmth, even though the temperature may be below hot weather conditions. The post-monsoon crop is the poorest, while at the same time it is the slowest to mature, usually a little over five months, e.g., from October 13, 1922 to March 20, 1923, being occupied in the process. The longest life-cycle implies primarily the driest season and secondly the coldest.

The third or pre-monsoon crop in Mysore is better than the preceding one, but not to be compared with that of the rainy season. It occupies the least time, viz., from three and a half to nearly four months, a combination of sufficient rainfall with high average temperature producing the shortest life-cycle. During the close of the hot weather there are usually several showers of rain from May onward.

A delay in these showers tends to lengthen the life-cycle; during the season from March 20 to July 16, 1923, the crop took nearly four months to mature.

Numerous observations have shown that the mortality among male larvæ is greater than among females. During the monsoon generation there was one male for each female, while during the winter season there were two males for one female. The winter crop is thus poor in outturn of lac, owing to the preponderance of males, but valuable for the continuance of the brood into the next generation.

Butea frondosa Lac.—In northern India lac is grown on *Butea frondosa*. Its insect (re-named by the author, *Lakshadia indica*) gives two crops of lac per year. One takes 3.5 months during the monsoon, the other 8.25 months of the winter and summer seasons, which is a period of less rainfall.

Following the distinctions developed in this paper, the crop collected in October, called in the north the Katiki crop, may be described as the monsoon-fed crop, while the Baisakhi or June is really a dry season crop. Statements vary as to which is the larger. Lindsay and Harlow state that usually the Katiki, or the crop with the shorter life-cycle is the larger, but that there are exceptions, one such locality being Palamau. Since November 1921 the author has been supplied with lac from this locality. The full-grown female insects at the end of the monsoon were invariably larger than those of the dry season. The generation of larvæ that swarmed from the monsoon-fed crop gave rise to more males than the generation of larvæ issuing from the dry season crop. The number of winged males in the post-monsoon season was always greater than during the monsoons. There seemed no evidence from consideration of the size of the insects or from determination of the sex-ratio in the larvæ to warrant making Palamau an exception to the general rule. Differences in the yield of lac per insect, dependent on factors other than sex, may be the basis of the statement.

Schleichera trijuga.—This host-plant produces the best quality of lac, known as Nagoli, the insect having been named by the author *Lakshadia nagoliensis*. For three seasons, brood-lac has been received from Raipur and Sohagpur. Inoculation experiments have shown that this species is least affected by moisture, the ratio between males and females among the larvæ remaining more or less constant, and the least divergent among all species. Winged males, though rare, were more frequently reared from the generation of larvæ swarming from the monsoon-fed crop. The absence of divergence in the sex-ratio during different seasons explains why crops of Nagoli lac are far more uniform than those on *Butea frondosa*.

Acacia arabica.—In Sind lac is grown on *Acacia arabica*, and its insect (termed by the author *Lakshadia sindia*) is the nearest approach to *Lakshadia communis*, with regard to its sexual dimorphism. The monsoon-fed crop contained well-grown individuals, but the larvæ gave rise to a preponderatingly large number of males, all of which were winged. A specimen of stick-lac collected at the end of the dry season showed small isolated colonies, and a number of scattered parthenogenetic crown-shaped cells. It seems that the locality where *Acacia arabica* trees are grown is irrigated by a canal, and that floods in the river Indus supply the area with excessive moisture during the monsoons.

Misra states 'attempts to grow lac in Bihar from brood-lac brought from Sind were not successful,' but offers no explanation of this result. If the experiment was tried with monsoon-fed brood, then it was without doubt due to excess of males in the generation. It is stated that only one crop of any value is collected in Sind, and that at the end of the monsoon. This is to be expected in view of the preponderance of male larvæ in the generation following the monsoons.

CONFIRMATORY OBSERVATIONS. •

Reports are frequently made that heat kills the lac insect colonies. During 1918–20, famine conditions prevailed more or less throughout Hyderabad State, and especially in Nirmal, where *Lakshadia indica* is grown on *Butea frondosa*. The yield of lac crops, however, increased steadily in spite of the persisting drought. The monsoons of 1921 were rather severe and the next summer crop was a failure. The reason for this given by the local officers was as follows:—'Continuous heat had already killed most of the insects, and whatever was left was washed away by the recent heavy rains.' A visit to the locality in April, 1922, revealed the fact that most of the cells were parthenogenetic, and these were incompletely grown, showing death to be due to starvation. Altogether the appearance was identical with that of Sind lac collected in May-June, and the main trouble could be attributed to the heavy rains which induced a disproportionate increase in males. These succumbed to the influence of drought rather than heat, and under these circumstances the females became parthenogenetic and also showed a high mortality, on account of insufficient food. The root of the trouble lay, therefore, in excess of previous rainfall rather than in the following summer heat.

Opinions hitherto published¹ differ as to the best season for the introduction of lac cultivation. In the light of what has been said in

¹ Cf. Starte, *Indian Forester*, June 1919, p. 336.

the foregoing pages, it will be clear that brood-swarmling at the end of monsoons is inferior, and that absence of moisture causes high mortality, and that therefore the best season for inoculation is at the commencement of the monsoons, using by preference brood-lac from localities with a low rainfall. It has been observed that what has appeared to be a very poor quality of brood-lac, with cells of medium size, has given excellent results in growth during the monsoons, the efficiency, no doubt being due to a greater number of female larvæ.

In further support of the conclusion that the effect of moisture is to produce more males, it may be said that this also holds true of parasites. In rearing *Coccophagus Tschirchii*, a parasite of *Lakshadia mysorensis*, the insects emerging from the summer crop of lac were found to be all females with one or two exceptions, while the parasite reared from the monsoon crop gave far more males, although the females still exceeded. *Eretmocerus Dewitzii*, a parasite on *Lakshadia communis* gave males only, on rearing at the end of the monsoon.

The males of *Elasmus Colemani*, a useful hyper-parasite feeding on *Eublemma amabilis* caterpillars, are most common at the end of the monsoons.

A species of chalcid reared before the monsoons from a caterpillar feeding on *Shorea talura* leaves gave a pure culture of female parasites, while the parasites reared from a certain wax insect turned out to be all males at the end of the rainy season of 1923.

The effect of moisture is therefore apparent not only in the direct plant feeders, as lac insects, but also in their parasites and even hyper-parasites, and seems to be a phenomenon of quite wide occurrence.