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THE ECONOMIC ASPECT OF INSECT ASSOCIATIONS WITH SPECIAL REFERENCE TO SOUTH INDIAN COCCIDAE (SCALE INSECTS AND MEALY BUGS)

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The existence of such phenomena as parasitism, symbiosis, commensalism, cannibalism and other curious associations in the animal world is a fact well known to all biologists; but as far as the writer is aware such relations are nowhere found in such numbers and in such extraordinary and remarkable varieties as in the realm of insects.

'Those fleas that do us bite
Have other fleas that bite them,
And those in turn have others
Ad infinitum.'

This well known doggerel describes in a pithy way the web of life among insects. The significance of such mutual associations, the benefit or disadvantage of such affinities to the individuals concerned in their struggle for existence and their effect, if any, on other organisms in nature, and especially on man, are therefore problems of great interest and well worth the attention of not only the entomologist or zoologist, but also that of every biologist and even economist. Such a study forms an important aspect of that branch of biological science known as *Ecology*. Insects in their superior numerical strength, in their diverse varieties, in their easy dispersal and wide distribution, and in their remarkable relations to other forms of life, afford numerous interesting examples for the study of this branch of biological study in its multifarious aspects. Very little work appears to have been done in this line, at any rate, on insects in India. The writer has been trying to do something in this direction by a systematic study of the Coccidæ of South India, their relations with other forms of life and the economic importance, if any, of such associations; and this paper is designed to place on record the results of a preliminary study so far made.

General organisation and life history of Coccidæ.—Before coming to the main theme of the subject, *viz.*, the associates of Coccidæ, their inter-relations and the importance of those affinities, it may not be out of place to indicate very briefly the salient features in the general organisation and life history of the Coccidæ which might have a bearing on the subject of the paper. The insects included in the family Coccidæ belong to order of bugs (*Rhynchota*) and are closely allied to plant lice in various ways. The great majority of these are minute forms, the largest among them not exceeding 15 to 20 m.m. in length. The general morphological characters and the features in the life-history are more or less similar throughout the group. In all cases the insects secrete a covering for the body which may be of hard chitin, soft wax, hard

resin or mealy matter, and with a few exceptions the greater part of their lives is spent in a stationary condition on the food plant, and for all outward appearance they resemble lifeless encrustations on the plant surface. A generation of coccids starts with the swarming of hundreds of fairly active larvæ or young ones out of the batch of eggs from under the mother scale; these which are almost microscopic in size and which possess all insect characters such as legs, feelers, eyes, etc., after restlessly wandering over the food plant for sometime, which may range from a few hours to three or four days, anchor themselves on the juicy parts of the plant by means of the needle-like feeding tube. Soon after fixation the larvæ cast their first moult and in that process lose their conspicuous legs and feelers; the characteristic scaly or mealy secretion now begins and the insect feeds and grows in this position. From this stage every female becomes fixed for life, but the male larva after a few days emerges out of its scale as a slow moving adult insect with all insect features and one pair of wings in most cases. These crawl over the female scales which are mature by this time and after fertilizing them die away. The fertilized females feed and grow very vigorously from this time onwards and in a few weeks the gravid female scales filled with eggs and covered with profuse secretion become conspicuous objects on the food plant; before the second generation of larvæ emerge the soft body of the female shrivels up and it dies under its scale. The morphology and life history briefly noted above are similar in almost all species of the group. In some cases no males have been discovered and reproduction has been found to take place by the process of 'agamogenesis' (the female producing young ones without the help of the male) as is often found in plant lice and a few other insects.

Coccid associates.—The small size of the Coccidæ, the structural degeneration they pass through in life, their practically stationary existence, their easy dispersal and wide distribution, the peculiarities in their life histories and their enormous powers of multiplication, all these evidently exert a considerable degree of influence on their ecological characters, and one important result is the tendency on the part of other forms of life to take advantage of one or more of these peculiarities in different ways and thus become very often unwelcome associates. In the case of the Coccidæ such associates are of different categories, though almost all of them belong to the class of insects. The more important of these forms may be divided into two main groups according to their habits, viz. *Predators* and *Parasites*.

Among the well known predators on the scales and mealy bugs are the beetles known popularly as the '*Ladybirds*', small and medium sized spherical creatures, the larvæ of which greedily devour eggs and larvæ of scale insects of different kinds. These beetles are very partial to soft scales and mealy bugs; the general appearance of some of these beetle larvæ is very similar to some mealy bugs and often the predator is mistaken for the victim. Of the

other predatory insects associating with scales and mealy bugs we have the *Chrysopas* or 'lace wings' belonging to the group *Neuroptera*; the larvæ of these pretty insects have formidable jaws with which they attack young scales and feed on them. Of occasional importance are some flies of the family *Syrphidæ* (Hoverflies), the wormlike maggots of which attack and feed on the eggs and larvæ of Coccidæ. Compared to the ladybirds, the relation of these lace wings and flymaggots to coccidæ may be regarded as of minor importance. Among other predators on coccidæ noted till now in South India are two or three species of *Lepidoptera*—one being a butterfly larva and the others the caterpillars of moths.[1] Among butterflies a species of Blues [2] is the only one known to the writer which has been found to seriously interfere with the economy of Coccids. The caterpillar, unlike others of the group which are phytophagous, lives in the midst of mealy bug colonies feeding on them and thus destroying them in numbers. The thickset fleshy larva covered with a white mealy coating slowly moving in the midst of a colony of mealy bugs forms an excellent example of insect camouflage. Its chrysalis found on the plant surface presents an appearance not unlike the face of a monkey in general contour, and is known as the '*monkey face pupa*'. This butterfly has been noted on two or three kinds of mealy bugs in Coimbatore. The moth caterpillars do not, like the butterfly, confine their attentions to mealy bugs alone, but are found in the company of other coccids also. Three or four species have been noted in India; of these the commonest one [3] in South India associates with some of the very common and destructive species of Coccidæ and acts as an important natural enemy of these. The caterpillar may be found in the midst of the scale colonies covered with a case or house made up of the empty scales of its victims cemented together; with this protection it moves about the scales colony devouring the victims one after the other until it pupates, fixing itself under the covering on the plant surface. Another moth [4] was found as a predator on a new species of giant coccid *Aspidoproctus xyliæ* which the writer discovered on rain trees in Coimbatore in 1924. The caterpillar of this insect weaves a silken band around the scales thereby preventing all the embryos emerging out and then feeds on these creatures inside the scale. Sometimes 2 or 3 caterpillars are found inside each scale. Some notes on the bionomics of these Coccid-feeding lepidoptera are recorded in a paper [5] read by the author at the Bombay Session of the Indian Science Congress in 1926.

The Coccid associates of the other important category are the numerous 'Parasites'. Most of these are internal, passing their early stages inside the bodies of scale insects and their activities are therefore not so evident and easily understood as in the case of the many predators. The parasitic forms affecting Coccidæ are mostly Hymenopterous wasps of the family

[1] Belonging to the genera *Eublemma* and *Euzophera*.
[2] *Spalgius epius*.
[3] *Eublemma scitula*.
[4] *Euzophera cocciphaga H*.
[5] B. J. xxiii. 1929. pp. 668-675.

Chalcidæ, and many of them are very minute insects. It is often not easy to state whether a colony of Coccidæ is inhabited by parasites or not by a casual observation; for, in many cases until after the emergence of the adult parasite, hardly any external sign is visible. The usual indication of parasite infestation among scales is the presence of minute holes of emergence on the scales of the victims, and in some cases abnormal body swellings or colouration are also signs of the presence of an internal associate. In the case of parasitism it is also often found that more than one kind associate with a scale, and in such cases the interrelations between the different parasites on the one hand, and their connection with the Coccid on the other hand become problems which can be solved only after very careful observation on the bionomics of all the insects concerned. Examples are known where one parasite is not a direct associate of the coccid, but only a secondary relative—that is, it parasitises the original parasite of the coccid or it may be a parasite on a predator on the coccid host. Without a clear understanding of these interrelations, the economic aspect of such associations in an insect complex is liable to be misunderstood and cases are known where such mistaken ideas have been formed. Among a few such cases noted by the author in his studies of South Indian coccidæ one is worth mentioning, *viz.*, the author's discovery of a wasp parasitic on the predatory moth caterpillar. This wasp which was many years ago (1895) bred out from lac insects in Ceylon was considered to be a primary parasite of the lac coccid until the recent discovery of the fact that the wasp had nothing to do with the coccid but lived as a parasite on the predatory moth caterpillar. Some observations on the bionomics of this interesting insect[1] are given in the author's memoir[2] on the *Nim* scale.[3] Thus, in the study of Coccid associates those that are parasites demand a more careful and thorough investigation before we attempt to interpret their relationships, particularly their economic value. Among other parasites of minor importance are some small flies of different kinds, chiefly found on soft scales and mealy bugs. Besides parasites and predators coccidæ occasionally share the attentions of a few other insects, though not to such an extent as those of the former groups. Commonest among these are different kinds of ants; these visit coccid colonies for the honeydew which many soft scales and mealy bugs secrete in profusion. When the secretion is very abundant, as in the case of some destructive species and the honeydew often wets the foliage of the infested plants, swarms of bees and wasps of different kinds visit the Coccid colonies. Though such relations are only casual they also play their part in the economy of the scale insects concerned as is explained below. In the following table the associates so far known of South Indian Coccidæ are given, briefly indicating the status of each.

[1] *Aphrastobracon flavipennis*. Ash.
[2] Memoirs of the Department of Agriculture. Pusa. Ent. Series viii. 1925, pp. 127–155.
[3] *Pulvinaria maxima* Gr.

Insects associated with Coccidae in South India

Coccid	Predator	Parasite	Others
1. *Aspidiotus tamarindus* G.		*Comperiella* n. sp.	
2. *Mytilasis piperis* G.		A Eulophid chalcid	
3. *Chionaspis aspidistræ* S.	*Chilocorus circumdatus*		
4. *Chionaspis grammis* G.		*Adelencyrtus chionaspidis* *Aphelinus mytilaspidis*	
5. *Pulvinaria psidii* G.	*Eublemma scitula*	*Encyrtus flavus* *Coccophagus sp.?* *Microterys kotinskyi*, Full.	
6. *Pulvinaria maxima* G.	*do*	*Aphycus* n. sp. *Perissopterous* n. sp.	
7. *Ceroplastes cerilerous* A.	*do*	*Scymnus coccivora* R. *Scutellista cyanea*	*Aphrastobracon flavipennis* (wasp.)
8. *Inglisia chelonoides* G.		An aphelenine chalcid	
9. *Ceroplastodes cajani* G.	*do*	*Chiloneurus* sp. *Metaphycus* n. sp. and *Anicetus ceylonensis*, How.	
10. *Lecanium nigrum* N.	*do*	*Anicetus ceylonensis*, How *Scutellista cyanea*, A new Genus and species of Encyrtus *Microterys kotinskyi*, Full. *Encyrtus barbatus*, Tumb.	
11. *Lecanium haemisphaerica* T.	*do*	*Comys rufescens*, *Coccophagus* sp.	
12. *Lecanium viride* G.	*Chilocorus nigritus* and *Chilocorus sexmaculata*	*Coccophagus and Aphycus* sp.	*Cremastogaster* (ant.)
13. *Lecanium diserepans* G.		*do*	
14. *Anamalococcus indicus* G.	*Eublemma scitula* R.	*Elasmus indicus*	*Aphrastobracon flavipennis*
15. *Pseudococcus citri* R.	*Spalgius epius*	*Tetracnemus* n. sp.	*Camponatus*, (ant.) (wasp.)
16. *Phenacoccus insolitus* G.	*Scymnus coccivora* R.	A Eulophid chalcid	
17. *Phenacoccus iceryoides* G.	*Spalgius epius*	3 or 4 small chalcids	
18. *Tacchardia lacca* K.	*Eublemma scitula*	*Gampyloneurus indicus* R.	*Aphrastobracon flavipennis*
19. *Aspidoproctus xylic* G.	*Enzophera cocciphaga*		(wasp.)
20. *Icerya Oegyptiaca* D.	*Scymnus coccivora*	2 small chalcids	

[*Note*. This study is still incomplete and the new forms are being described elsewhere.]

It is hardly necessary to add that the above list represents but a very small fraction of Coccid associates yet to be studied in South India; the author has only just touched the fringe of the subject and there is no doubt that as a result of further investigations a good deal more may be added to our present knowledge on the subject.

Significance and economic aspect of these relations.—We may now consider the significance, the effect on the individual forms concerned and the economic importance, if any, of these relations between Coccids and other organisms. While on the one hand these insects have the capacity to multiply rapidly and enormously and often cause serious and extensive damage to cultivated plants, on the other hand their practically fixed life, their small size and the absence of any appreciably defensive organs render it easy for other forms of life to associate with them and enjoy the benefits of such a relation. In some cases the coccid itself gains the advantage by getting dispersed and distributed by these agencies; this is very much facilitated in the case of the soft scales and mealy bugs which secrete the characteristic honeydew, often in abundance to attract numerous casual visitors like ants, bees, wasps, flies etc. During the brief sojourn that these make among the scale colonies to lick up the sweet fluid, many young coccid larva and eggs get attached to their bodies and are carried away to other trees and places. This is very commonly noted by the author in Coimbatore in the case of the *Nim* scale.[1] Ants play a very prominent part in this part particularly in its relations with mealy bugs. The common black ant[2] and the notorious arboreal red ant[3] are striking examples of cocciphilous ants in South India; the former often builds its nests at the foot of coccid-infested trees and this is commonly seen in connection with the *Babul* scale[4] on the Coimbatore farm.

While these casual visitors in most cases play a more or less friendly role, the influence of the predators and parasites on the economy of the coccids is far greater and much more important. In most cases they are Coccipha-gous—direct enemies of the scale. Whole colonies of young and soft bodied scales are wiped away in certain seasons by both predatory and parasitic enemies. The ladybird beetles are particularly important in this respect; they are effective against the young of the armoured scales and against the soft and freely moving forms also. Some of these ladybirds have been known to completely control many scales in the different parts of the world. In South India there exist a few beetles which play some part in this direction. As an effective predator on the *Nim* scale the writer discovered and noted the bionomics of a small brownish beetle which he has recently described.[5] Each grub of this beetle devours hundreds of the eggs and minute larvæ of the host and acts as an efficient natural enemy. The story of the parasites is similar in many cases. In certain seasons scale insect infestation is suddenly

[1] *Pulvinaria maxim* Gr. [2] *Camponotus.*
[3] *Oecophylla.* [4] *Anamalococcus indicus* Gr.
[5] *Scymnus coccivora* R. (Journal of the Bombay Nat. Hist. Soc. xxx. 1925. p. 491.)

checked as if by magic and a close investigation often reveals it to be the remarkable work of minute parasites; this is occasionally found to be so in the case of the common black scale [1] almost a perennial pest on the Portia (*Thespesia populnea*) trees on the Coimbatore farm. All these are evidently provisions made by nature to keep such extraordinarily prolific insects under some control and help to keep up the natural balance of life in the world. The sudden outbreaks of scale pests, for the matter of that, of all pests during certain seasons and a lull in their activities during other seasons have to a great extent to be attributed to the effective or tardy influence of friends and foes, through other important factors like food and climatic conditions equally exert their influence in maintaining the necessary balance of life in nature. A proper study, therefore, of these interrelations and the different factors connected with man's welfare, will not only be valuable from a purely scientific and ecological point of view for the biologist, but it would also open up a vista of great economic value to the farmer and the economic entomologist. The economic importance consists in the correct understanding of various such relations and the proper utilisation of the knowledge gained by such investigations to the best advantage. Advantage has been and is being taken of the results of such studies in many countries at present. In many tropical and sub tropical regions it has been found by experience that the ordinary and time-honoured methods of insect pest control, such as spraying, dusting, fumigation etc., do not prove very effective in checking some of the worst pests like scale insects, fruit flies etc., and entomologists and agricultural authorities in different parts of the world have nowadays begun to feel the need for the trial of the 'Biological methods of pest control' *viz.*, the encouragement of the existing natural enemies of pests and if necessary the introduction of beneficial forms from other places to combat a local pest. It may be interesting to note that the pioneer attempt in this line was directed to check a notorious Coccid pest—the cottony cushion or Fluted scale.[2] This pest was causing terrible havoc in the Citrus orchards of California in the early eighties and was found to withstand all artificial methods of control. In 1889 a United States Department officer Mr. Koeble succeeded in finding in Australia, the native home of the pest, an effective enemy—the '*Vedalia*' ladybird and introduced it into California. The experiment proved a remarkable success and since then a similar line of pest control began to be studied in almost every country where this pest gained entry. This notorious insect got itself distributed into many parts of the world like Spain, Italy, South Africa and even Ceylon and began to assert itself, but did not somehow or other enter India and was considered one of the many undesirable foreign insect pests as may be seen from the author's paper [3] 'On some foreign insect pests which we do not want in India.' But unfortunately it has recently gained admission into the country

[1] *Lecanium nigrum*, N. [2] *Icerya purchasi*. M.
[3] *Agricultural Journal of India*. xiv. 1919. p. 500–511.

and was first noted on the Nilgiris in the spring of 1928, on some Australian wattles. It is not known exactly how and when it came in. The insect began to cause some appreciable damage and the Madras Government has recently introduced the '*Vedalia*' beetle [1] from California and the result of the experiment is keenly watched. It will be interesting to note side by side with this account of the introduction of the predatory beetle to check a scale, the recent introduction into India of a new Coccid in the interests of man. With the object of destroying the 'prickly pear' which is a bad pest in different parts of South India—a species of *Cochineal* insect [2] has been recently introduced into parts of the Tinnevelly District. During a recent trip to Tinnevelly the writer found the newly introduced scale insect spreading rapidly and destroying the prickly pear weed appreciably. These two are just two of the many examples to show the economic importance of a study of the bionomics of the Coccidæ in the various aspects, food habits, associates etc. It must, however, be emphasised, again that in all such cases where it is intended to utilise the knowledge so gained of coccid associates for the good of man it is very essential that the following points should be accurately and thoroughly investigated before any attempts are made to take advantage of such relations.

i. The complete life history of the coccid in all its aspects.

ii. A thorough study of the associates of coccids in the same manner; in this study a proper investigation of the interrelations between the various associates themselves is of equal importance—such as the connection between parasites, co-parasites, hyperparasites etc. This aspect is of the utmost importance in any attempt to introduce an extraneous organism; for, an unknown predator or parasite of the beneficial immigrant itself may gain entry without our knowledge and in some cases the new arrival itself may prove an undesirable one and unexpectedly become a pest in its adopted home. In such cases the remedy, unfortunately, will be worse than the disease.

This shows that all such investigations should be done carefully and thoroughly and the results applied for economic use only after sufficient and satisfactory trials.

The author has tried to deal with this subject only in a preliminary way and that only in relation to one group of organisms viz. Coccidæ. He will feel sufficiently repaid if the notes contained in this paper serve in any way to stimulate others working on insects to bestow a little more of their attention to the bionomics and ecological relations of insects—an aspect of Entomology—on which depend a great deal the future possibilities and success of the economic entomologist. As explained above the study is not only of absorbing interest to the pure scientist, but is pregnant with economic possibilities,

[1] *Vedalia cardinalis*. M.
[2] *Dactylopius tomentosus*, L.

STUDIES IN THE COST OF PRODUCTION OF CROPS

III

Name of Crop : Paddy. Area : 2½ Acres.

Village : Seshanchavadi.

Locality : Salem Taluk (Sale

General notes. The ryot in question is a farmer with some capital and has engaged permanent labourers under him on monthly wages. He farmed his lands himself with his own cattle. Besides ploughing operations he engaged his cattle for irrigation, as the lands were garden lands, and the irrigation had to be done wholly from the well. For a period of about three weeks the mhotes were not worked on account of rains. During the remaining period, the mhotes were constantly at work. In carting green manure, weeding and harvesting operations, the farmer had to employ outside labour. The area cultivated was 2½ acres under the well, and the local paddy variety *Sadai Samba*, was transplanted. The permanent labourers were paid only small amounts ranging from Rs 3–8–0 to Rs 7. In the case of cattle labour, the charges of feeding cattle were high, as they were fed with groundnut-cake or cotton-seed besides bran. The cattle were better than those maintained by smaller ryots in the village. The three pairs of cattle cost in all about Rs 400.

Economic planting was adopted.

Seed was sown in seed-bed on the 5th August 1928. The seedlings were transplanted when they were 40 days old. Harvesting was done on the 22nd of January 1929.

Details of Cultivation and charges

Particulars of Work	Men @ 8 as.	Women @ 4 as.	Pairs @ 8 as.	Amount	
				Rs A P	
Preparatory Cultivation					
Ploughing the land for 1½ months	45		45	22 8 0	
Total ...	45		45	22 8 0	
Seeds and Sowing					
Ploughing seed bed, irrigating	12	...	12	6 0 0	Own cattle used
Manuring seed beds with leaves	...	...	3	1 8 0	
24 bundles @ 2 annas per bundle	...	...	...	3 0 0	
Cost of seed—30 *vallams*—at 5¾ lbs. per *vallam*	...	...	...	10 0 0	
Pulling seedlings and transplanting	6 @ 6 as.	36	...	11 4 0	
Total ...	18	36	15	31 12 0	
Manures and Manuring					
Cost of 280 bundles at 2 annas per bundle on contract ...	...	...	...	35 0 0	
Trampling leaves	15 @ 4 as.	21	...	9 0 0	
Total ...	15	21	...	44 0 0	

After cultivation					
Weeding	18 @ $2\frac{2}{3}$	54 @ 3 as.	...	13 2 0	
Total ...	18	54	...	13 2 0	
Irrigation					
Irrigating by mhote—for about 3 months leaving about 3 weeks of rainy days—at 2 pairs per day on an average ...	150	...	150	112 8 0	At 10 as. per pair including men
Charges for 3 mhote buckets, tail ropes, and mhote ropes ...	...	...	...	30 0 0	
Wages of chucklers, carpenter, etc.	...	...	...	3 0 0	
Total ...	150	...	150	145 8 0	
Harvesting (contract work)					
Harvesting, bundling, threshing. $1\frac{1}{4}$ *khandayam* of paddy given as wages at Rs 12 per *khandayam* of 225 lbs. ...	...	...	...	15 0 0	
Stacking straw—after cattle threshing	6	8	6	4 8 0	
Total ...	6	8	6	19 8 0	
Assessment	...	...	...	7 13 0	
Interest on the investment of cattle Rs 400 @ 12% for 6 months.	...	...	...	24 0 0	
Interest on the capital expended	...	...	...	6 0 0	
Mhote ropes, manure leaves, etc., say on Rs 100 @ 12% for 6 months	...	...	...	20 0 0	
Depreciation	...	...	...	1 5 0	
Total ...	...	...	...	59 2 0	
Grand Total ...	...	...	...	335 8 0	

Cost of Produce and Profit

	Per Plot	Per Acre
Yield of paddy		
Grain	8,550 lbs.	3,420 lbs.
Straw	7,500 „	3,000 „
Value of produce	Rs A P	Rs A
Grain at Rs 12 per *khandayam* of 225 lbs.	456 0 0	182 8 0
Straw—7,500 lbs. at 100 lbs. per Rupee ...	75 0 0	30 0 0
Total ...	531 0 0	212 8 0

Total value per acre ...	...	212 8 0
Less expenses per acre ...	...	134 5 0
Balance, profit ...	...	78 3 0