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EXTRA-FLORAL NECTARIES IN *HEVEA BRASILIENSIS*

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Eventhough the source of honey in most other plant species is the flower, in the case of rubber tree, it is the leaf. Bee keeping in rubber plantations is getting acceptance now a days. As early also as in 1968, work was conducted on the extra floral nectaries of rubber and a paper was published describing three types of nectaries. Of these, one was an original finding by the author Smt. L. Thankamma, now working as Mycologist in the Rubber Research Institute of India. Though some articles are written and published in journals on the topic, most of the rubber planters are still unaware of the source of honey in rubber. There is also a feeling among so many that rubber honey is produced in the flowers. We are now reproducing the paper published in the Rubber Board Bulletin Vol. 9 No. 4 (1968). The late K. V. George, the co-author of the paper was Deputy Director in the Rubber Research Institute of India in 1968 and later became the Director of Cardamom Development, Cardamom Board, Ernakulam.

Hevea brasiliensis is monoecious with diclinous flowers arranged in panicles. According to Dijkman (1951), the plants are typically entomophillous cross pollinators. The studies of Mass (1919), Morris (1929), Seibert (1947), Muzik (1948), Warmke (1951, Sripathi Rao (1961) and Jayarathnam (1965) also show that insects play an important role in the pollination of *Hevea brasiliensis*. Various characters of the flower, viz, colour, fragrance, sticky nature of the pollen and stigmatic surface, further point to insects as the most favourable pollinating agents. Considering that *Hevea brasiliensis* is predominantly adapted for insect pollination, that various insects including honey bees have been observed to be active and numerous during *Hevea* flowering season and that bee hives kept in rubber gardens during flowering season, yield plenty of honey, it is to be expected that nectar is secreted by some part of the plant.

While no floral nectaries have been observed in *Hevea brasiliensis*, two types of extra-floral nectaries have been reported. Martius (1873) in his "Flora of Brazil." and Delpino (1887) in his studies on extra-floral nectaries, mention about the presence of nectaries, on the poliage leaves viz. the petiolar nectaries. The structural details of these petiolar nectaries are described by Daguillan and Coupin (1903). Parkin (1904) in his paper, "The extra-floral nectaries of *Hevea brasiliensis*," reports the occurrence of nectariferous bud scales, in addition to the petiolar nectaries and gives an account of their structure possible evolution and functions. Bobilioff (1923) in his "Anatomy of *Hevea braiiliensis*," while describing the structure of the petiole, mentions about the presence of a small disc with several glands on the petiole at the point of insertion of the leaflets and these are reported to function only in the young stage, when they give off excretory products. He also reports presence of special openings, viz., hydathodes, seen as pin holes, on the lower surface of the leaves and states that these are of assistance in getting rid of excess water, in a liquid form, at times when the stomata fail to function.

In the present paper, the authors have attempted to give a detailed account of the extra-floral nectaries already reported by earlier workers, viz., petiolar nectaries and nectariferous bud scales. Further, occurrence of another nectariferous structure is also reported. These are the glands on the lower surface of the leaves and wrongly defined by Bobilioff (1923) as hydathodes.

Observations

Three different glandular structures, all foliar in origin, were observed to secrete a colourless, sticky and sugary iiquid, viz., nectar. These are the nectariferous bud scales, nectariferous glands on the petiole tips and the nectariferous glands on the lower surface of the leaf lamina. The morphology, anatomy and functions of these glandular tissues, observe to secrete nectar, are described.

Nectariferous bud scales

In young shoots of *Hevea*, a varying number of small, green, fleshy scales are seen developing on the stem, towards the terminal bud, below the whorl of tender flush (Fig. 1). Normally, these scales subtend an axillary vegetative bud, but during flowering

season, the top most scales may subtend inflorescences. In young actively growing shoot, the transition from these fleshy scales to normal leaves can be clearly seen (Fig. II). The lower most scales are short, roundish, gradully tapering to a pointed tip and highly curved outwards. The outer convex surface is slightly raised, pale, yellow, made of glandular tissue and with a longitudinal median groove. At the pointed tip a number of trichomes are present. Towards the terminal bud, the scales gradually become more elongated and straightened. The glandular portion shows gradual reduction in size and gets confined to the middle region of the outer convex surface. Simultaneously, the longitudinal groove gets less prominent and in the top most scales they are not visible. Along with the elongation of the scales and simultaneous reduction in the glandular tissue, three abortive leaflets appear at the tip of the scale as thin bristles. The upper most scales are devoid of the glandular tisue and they carry at their tips three leaflets which resemble the normal leaflets in shape and structure, but much reduced in size (Fig. II,7-8). Few such scales resembling typical leaves except for their reduced size, may be seen just below the whorl of true leaves, These as well as the glandular scales below are shed as the true leaves mature.

The glandular tissue on the lower fleshy scales secrete nectar profusely, during flowering season. The nectar secreted collects into small droplets which often coalesce and trickle down. The drops of nectar are large in the morning hours, slowly drying up in the sun.

A microscopic study of longitudinal sections of the glandular scales showed that they are fleshy structures, composed mostly of parenchymatous tissue and poorly developed vascular elements bounded by cuticularised epidermal layer. The scale is bounded on all sides by normal epidermal cells, excepting the outer convex surface where the epidermal cells get modified into a glandular tissue, covered on the outside by thick cuticle. The glandular tissue is made up of thin-walled columnar or pappilose (shaped) cells and characterised by dense cytoplasm Many of these cells are divided by tangential walls into two or sometimes three daughter cells. Due to pressure of nectar secreted by these glandular cells, the cuticle bursts. Just below the glandular tissue, a layer of compact isodiametric parenchymatous cells is noticed, beneath which normal parenchyma is seen. In the parenchymatous tissue, vascular traces are seen small branches of which end below the glandular region (Fig. III).

Apart from the nectariferous bud scales, a few basal scales, which are small, thin and non-nectariferous are also observed (Fig. I-1). These basal scales protect the dormant bud and as soon as the bud sprouts, they shrivel, dry up and fall off.

Nectariferous glands on petiole tips

At the distal end of the petiole, in the region of insertion of the leaflets, a varying number of glands one to seven—usually three—are noticed. These glands are circular to oval or even irregular in shape, with slightly raised margins. Quite often, two or more of these glands are observed to unite attaining irregular shapes (Fig. IV). The glandular area is paler than the surrounding area.

In surface peelings, they appear as groups of small, nonchlorophyllated cells. In longitudinal section, the gland is seen to be made up of a group of thin-walled columnar cells, nonchlorophyllated, rich in cytoplasmic contents, as seen in the case of the glandular portion of the nectariferous scales. A cross-section of the petiole tip where the glands are situated, shows that the upper and lower epidermis are normal, except at the region of the glands, where the epidermal cells are modified to form the thin walled columnar cells. Many of these cells are divided by tangential walls forming two or three daughter cells. Beneath this epithelial layer, a single layer of isodiametric, nonchlorophyllated, parenchymatous cells is noticed, beneath which normal parenchymatous tissue is observed. Small branches of vascular traces arising from the central vascular tissue are seen ending below the glandular layer (Fig. V). The individual glands are observed to secrete small drops of nectar which often run together forming bigger drops. These glands do not function during the early stages of leaf formation or long after the leaves have attained full maturity. The secretory function is predominant following refoliation when the leaves have turned green, fully expanded and no more flaccid. Once the leaves are fully matured, the glands become functionless, the tissues shrivel and get discoloured.

Nectariferous glands on the lower surface of the leaf

These glands are seen as minute yellowish spots, numerous and irregularly distributed on the lower surface of the leaf. On microscopic examination, in surface view, these are seen to be more or less circular in outline and slightly raised above the surrounding surface, the glandular area being composed of small cells and delimited by a ring of highly lignified cells (Fig. VI). At the region of the gland, the leaf is slightly thick. The upper epidermis is normal. The depth of the palisade tissue is considerably reduced. Below this is seen a vascular trace, the end of which is towards the lower glandular portion. The region below is composed of compact parenchymatous cells, many of which are devoid of chloroplasts, in place of the normal chlorophyllated and loose spongy parenchyma. Below this, a compact layer of isodiametric cells, without chloroplasts is seen. Immediately beneath this, is seen the glandular layer, composed of thin walled columnar cells, (devoid of chloroplasts) and rich in cytoplasmic contents.

Some of these cells are divided by tangential walls into two cells. The lower surface of these cells is rounded and covered with a thick layer of cuticle (Fig. VII). The nectar secreted is seen as small droplets, suspended from the lower surface of the leaf, at the regions of the glands. A close similarity in the anatomy and functions of the three nectariferous glands described above is noticed. In all cases, the secretory epithelium consists of modified epidermal tissue in the form of thin walled, nonchlorophyllated and columnar cells, which by later tangential wall formation, forms two or three daughter cells in some cases, the glandular region is well supplied with vascular elements. Further, secretion of nectar has been observed in all the three cases.

In mature plants, these nectariferous glands normally function only for a short period, confined to the refoliation time, which significantly coincides with flowering. In *Hevea brasiliensis* refoliation and the more or less concurrent occurrence of the main flowering, normally occurs in this country, during January-March period and it is during this period, that these glandular tissues have been observed to be actively functioning, secreting nectar. In young rubber plants where several flushes of growth are produced in an year unlike the mature trees, functional nectariferous bud scales and nectariferous petiolar glands are noticed with each new flush of growth, which after a certain period become functionless. It was however observed that the nectar secreted was considerably low compared to the quantities secreted by the nectariferous glands in mature trees during flowering season.

Discussion

Earlier workers have reported the occurrence of two kinds of extra-floral nectaries, viz, the nectariferous bud scales and the petiolar nectaries, in *Hevea brasiliensis*. In addition to giving a detailed account of the structure and functions, of these two kinds of extra-floral nectaries the authors report the occurrence of a third kind of extra-floral nectary, viz, the nectariferous glands found on the lower surface of the leaves. Describing the occurrence of hydathodes in *Hevea brasiliensis*, Bobilioff (1923) states:

"On the lower side of leaves, besides the stomata, special openings are found whose function is analogous to that of the stomata. They may be seen as pinpoints on the lower side of the leaves. They arise as raised regions of the epidermis in which finally an intercellular opening is formed. The opening in the centre arises through the separation of cells and increases in size with the age of the leaf. Through this opening, the water exudes when transpiration through stomata does not take place" From the above description, it is clear that what Bobilioff has referred as hydathodes are the nectariferous foliar glands reported in this paper. Presence of one or more permanent openings is a characteristic of a hydathode. Though Bobilioff has reported the presence of such an opening arising by the separation of the cells, the authors could not observe any such opening in these foliar glands, even though leaves at varying stages of maturity were examined. Further, the secretion from these glands is a sweet and sticky liquid-nectar and not water as reported by Bobilioff. The absence of any opening, the presence of a secretory epithelium consisting of modified epidermal cells, similar to those noticed in the nectariferous bud scales and petiolar nectaries, the compact parenchyma below the secretory epithelium and the sugary nature of the secretion, are all clear indications that what Bobilioff described as hydathodes are really not hydathodes but nectariferous foliar glands.

Referring to the petiolar nectaries, Bobilioff (1923) states: "These glands apparently function in the young stage of the leaves. The openings arise through the splitting of the epidermal cells of the petiole." Contrary to the above observation, the authors could not find any openings in these petiolar glands, though several such glands at various stages of growth were examined. Further, these glands were not osberved to function till the leaves were fully expanded and mature.

Parkin (1904) reports that the nectaries of the foliage leaf are not prominent structures and that they do not differ as a rule in colour from the surrounding surface. The present observations differ from the above in that the petiolar glands are yellowish-green in colour in contrast to the green colour of the surrounding surface. The light colour of the glandular surface is due to the secretory epithelial layer.

Many entomophillous plants produce nectar, which attracts insects. Nectar is secreted by specialised cells either on the floral parts or on other structures outside the flower. Definite and elaborate structures adapted to secretion of nectar, occur in certain families e.g. Euphorbiaceae. In *Hevea brasiliensis*, a plant typically adapted for insect pollination, the occurrence of the three kinds of extra-floral nectaries described in the paper, could be considered as a feature providing attraction to insects. Parkin (1904) while describing the nectariferous bud scales and its functions, states: "The bud scale glands may be looked upon as attracting ants to keep off insects injurious to the developing foliage. As soon as the foliage leaves mature, their own nectaries become functional and the scale ones being no longer required, wither and drop off." Different types of ants have been observed by the authors feeding on the nectar from the bud scales of young plants. These may be keeping off insects injurious to the developing foliage. However, in the case of mature plants where refoliation and flowering are more or less simultaneous, it

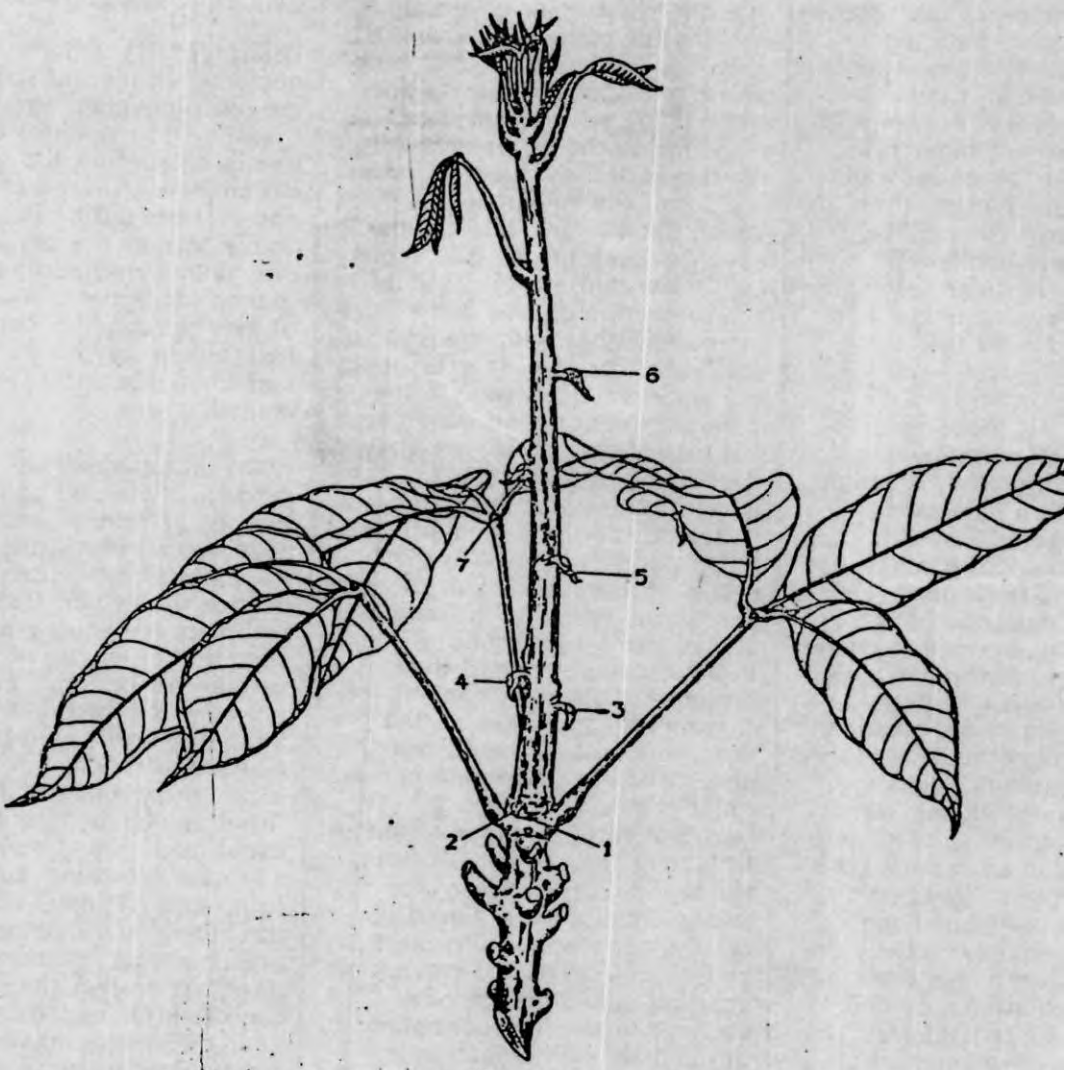

Fig - 1

Young shoot of *Hevea brasiliensis* showing glandular bud scales

1. Scar left by non-nectariferous bud scales.
2–6. Nectariferous bud scales. 7. Petiolar nectary.

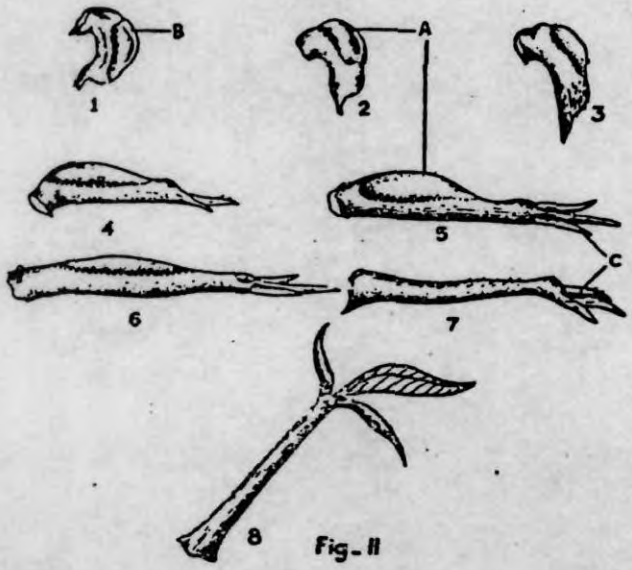

Fig. II

Nectariferous bud scales showing transition to foliage leaf

1-3. Highly curved lower bud scales.

4, 5, 6. Upper bud scales which are straightening out showing glandular area and highly reduced leaflets.

7 & 8. Upper most scales without glandular area and the leaflets more pronounced.

A—glandular area. B—median groove. C—reduced leaflets.

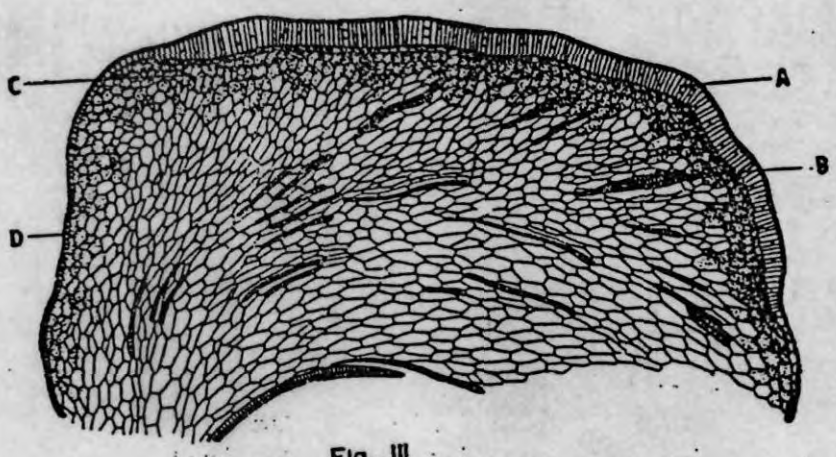

Fig. III

L. S. of nectariferous bud scale

A. Secretory epithelium consisting of modified epidermal cells.

B. Vascular trace. C. Chlorophyllated parenchyma.

D. Normal epidermis.

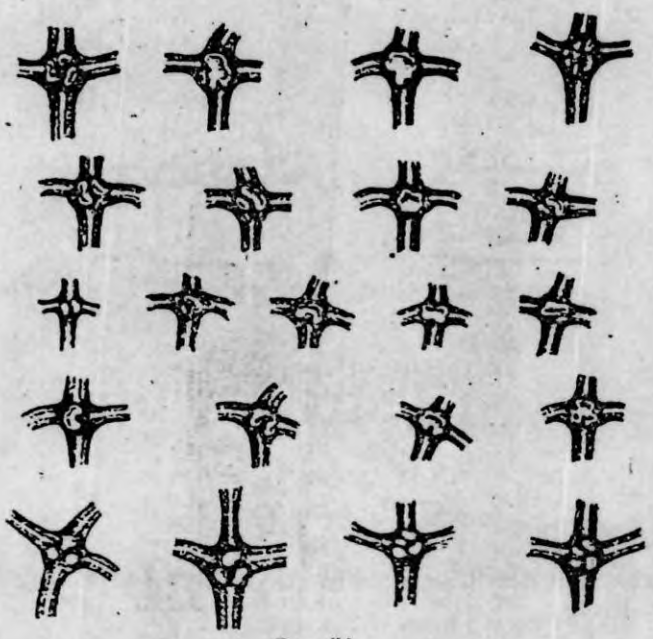

Fig - IV

Petiolar nectaries showing variation in size, shape and number

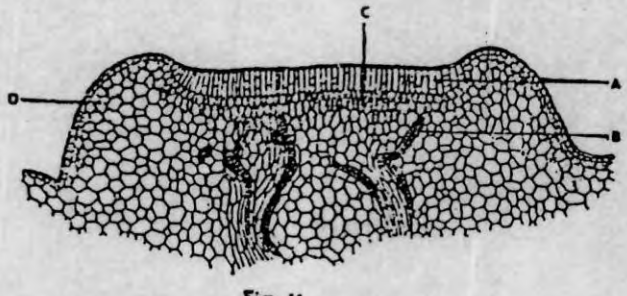

Fig. V

T. S. of petiole at the region of the nectary

A. Secretory epithelium. B. Vascular trace.
C. Chlorophyllated parenchyma. D. Normal epidermis.

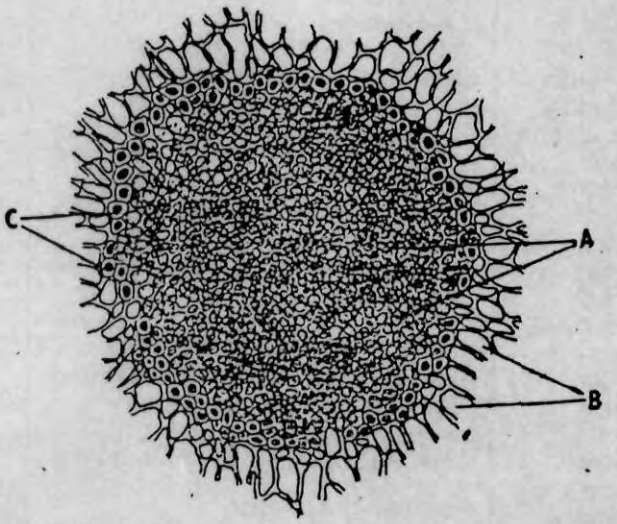

Fig-VI

Surface view of a nectariferous foliar gland.

A. Glandular cells. B. Normal epidermal cells.
C. Lignified cells delimitting the glandular portion.

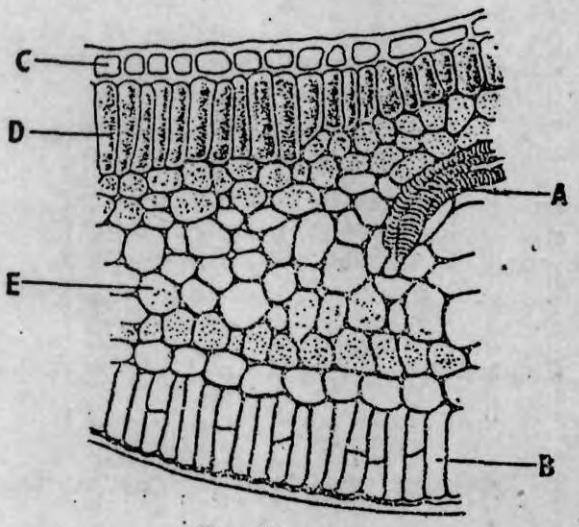

Fig-VII

T. S. of leaf through a nectariferous foliar gland

A. Normal upper epidermis. B. Vascular trace.
C. Secretory epithelium consisting of modified lower epidermal cells.
D. Palisade layer. E. Compact parenchyma.

would appear that the extra-floral nectaries serve mainly a function of attracting insects, some of which at least aid in pollination. It has been observed that all the three kinds of nectaries function simultaneously during *Hevea* flowering season. The bud scale glands have been observed to continue secretion of nectar even when the petiolar glands have developed and are functioning. It has also been observed that the quantity of nectar secreted by all the three kinds of nectaries are considerably more during the flowering season compared to other seasons. Further, Jayaratnam (1965) observed Indian honey bees feeding on the secretion from the petiolar nectaries and *Calliphorids* were found to perch on the ventral side of the leaves, when not visiting flowers and they were also found to feed on the nectar.

Summary

A short review of two kinds of extra floral nectaries of *Hevea brasiliensis*, reported by earlier workers is given. In addition to giving a detailed account of the structure and functions of the two kinds of extra-floral nectaries already reported, occurrence of a third kind of extra-floral nectary viz, toe nectariferous glands on the lower surface of the leaf, is also reported. Nectariferous bud scales are a characteristic feature of the young expanding shoots and they are present on both young as well as mature plants. There is close similarity in the structure of the three kinds of nectaries. Eech has a well defined secretory epithelium with a thick cuticle above. The secretory epithelium consists of modified epidermal cells, some of which may be two or three layered. In young plants, these extra-floral nectaries could be looked upon as attracting ants to ward off insects injurious to the developing foliage, but those on mature trees, during flowering season, could be considered as providing attraction for insects for aiding in pollination.

Acknowledgment

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RUBBER CONSUMPTION INCREASED

World rubber consumption increased in 1986 with United States showing a 1 per cent rise in demand. According to a report published by International Rubber Study Group, the world demand went up to 1.2 per cent in 1986 with Asia accounting for more than half of the increase. So also the synthetic rubber use rose by 1.5 per cent to 9.19 million tons and natural rubber demand went up 0.5 per cent to 4.38 million tons. Asian nations showed increase in rubber use. Demand went up 14% in South Korea, 10% in Taiwan, 6% in India, 5% in China and 4% in Malaysia.