CONTRIBUTIONS TO THE STUDY OF SPIKE-DISEASE OF SANDAL (*SANTALUM ALBUM*, LINN.).

Part XII. Ecology of Sandal.

By M. Sreenivasaya and S. Rangaswami.

The study of sandal in its natural habitat has a fundamental interest from the standpoint of the parasitic nature, and also in respect of the economic efficiency, of the tree, which is determined by (1) vigorous growth resulting in high volume increment, (2) profuse seeding, ensuring an extensive regeneration of species, (3) intensive heartwood formation rich in the valued essential oil and (4) resistance to disease and insect attack. In the case of the parasitic sandal these factors are mainly controlled through its associated host-plants; the richest soil which may be provided, by itself does not favour the growth of sandal, the nutrients of the soil being made available to sandal largely through suitable host-plants which are haustorised by sandal. Pot-culture experiments have established the interesting fact that sandal has a preference in general for host-plants of the leguminous type, which seem to favour its rapid and vigorous growth.

The frequency and quantity of seeding is influenced by the kind and number of hosts with which sandal happens to be associated. Pot-cultured sandals deprived entirely of their host-plants seed only once a year, usually in the month of November, and yield seeds with practically no germinating power, while sandals freely fed by hosts normally seed twice a year. It has been found that sandal-seeds collected from various localities vary widely in their germinating capacity; and a systematic study of the vitality of sandal-seeds in relation to the floristic composition of the host-groups should reveal the nature of the host-plants which impart to sandal the quality of bearing fruits in profusion and of high fertility.

It is believed that heartwood formation is influenced by conditions reputed to disfavour vigorous vegetative growth, but reliable and accurate data are not available in support of this theory. Girth for girth, a sandal struggling in a rocky soil and in association with xerophytic plants, has higher proportion of the oil-bearing heartwood than one thriving luxuriantly on a rich soil, enjoying good rainfall and nourished by vigorous hosts. But the girths of two such sandals are

not comparable as regards age, since in the one case growth is exceedingly slow, while in the latter girth-increment is rapid. It is not known whether heartwood formation is at all a function of age, but there is no doubt that it is influenced by the nature of associated host-plants and by the moisture conditions of the soil. Further, the percentage of essential oil in the heartwood has been found to vary with the ecological aspect of the locality. Heartwood from Javadis for example has the reputation of possessing a high oil-content, and in consequence fetches high prices.

The resistance of sandals to insect attack has a two-fold significance. Primarily, sandal is liable to attack by several insect types, tending to restrict growth, and secondly, certain types by virtue of their feeding habits and biological relationships are inimical to sandal as vectors of disease. It is well known that, generally, the internal physiological condition of the plant determines its predisposition to insect attack and this condition in the case of the parasitic sandal is influenced by its host-plants. The variety and quantity of insect fauna infesting a sandal will therefore depend upon the floristic composition of the host-groups nourishing it.

Analysis of pot-cultured sandal nourished by known hosts, has shown that the host has a considerable influence on the composition of the sandal sap, thereby rendering the plant more or less open to insect attack. By a judicious choice of host-plants, it should be possible to control the composition of the sap in such a way as to render it distasteful or repulsive to those classes of insects reputed to be vectors of disease. This would represent only a static type of immunity, and the sandal would succumb to disease if the infective agency attacked the plant through some means other than the insect.

Perfect and unqualified immunity is one which enables the sandal to combat the infection after its internal invasion, through some inherent mechanism. The parasitic sandal is possibly dependent on its host-plant for this dynamic defensive function as well, and herein lies perhaps the secret of a successful and rational elucidation of spike-disease, which has been causing heavy damage to some of the richest sandal-bearing tracts of Mysore, Coorg and Madras.

It has been observed that under natural conditions the sandal-bearing areas vary widely in their capacity to function in respect of the four main factors indicated above, as they are largely dependent upon the floristic composition of the areas. Table I shows that sandal attains higher girths and survives longer in certain areas than in others. The yield of heartwood also varies with different areas.

TABLE I.

Growth and heartwood formation in some sandal-bearing areas.

	Locality	Mean annual girth increment, inches	Percentage of heartwood	Average exploitable size, inches
Madras	Chitteries ...	0·75	4·77	60
	Nilgiris ...	0·60	12·60	36
	Javadis ...	0·66	4·00	...
	North Salem ...	0·25	3·70	...
Mysore	Heggad Devankote ...	0·40	9·09	31·5
	Chamarajnagar ...	0·40	5·10	36·0
	Hunsur ...	0·36	8·60	36·0

If natural regeneration of species can be taken as a true measure of reproductive capacity the self-sowing of sandal in different areas will be different, and this is found to be the case. The resistance of sandals to disease has also been found to vary widely with different areas. While some areas have remained immune to the disease in spite of their close proximity to infected areas, there are others which have succumbed to the infection in spite of their comparative isolation from sources of infection. It has been found that the rate of spread of spike-disease is higher in certain areas while in others the spread is very slow indeed, as can be seen from Table II.

TABLE II.

Locality	No. of Spiked Sandals		Observation period, months
	At start	At close	
Tholuvubetta ...	4	62	24
Mahadeswarangudi ...	1	13	33
Jawalgiri (Bungalow) ...	6	109	10
Jawalgiri (Cairn 53) ...	3	12	12

An ecological survey of some typical sandal-bearing areas was undertaken to determine the extent to which host-plants influence the parasitic sandal in performing its useful functions. Special attention has been given to the possible effect suspected of hosts in rendering sandal either susceptible or resistant to spike-disease. The

sylvicultural and other climatic characteristics prevailing in the surveyed areas are tabulated below.

TABLE III.

Locality	Elevation, feet	Soil	Type of forest	Average annual rainfall, inches	Temperature, mean	Humidity
Devarabetta Healthy	3,144	Disintegrated gneiss with rocky subsoil	Open scrub	31·7	21·5	76
Devarabetta Spiked	3,150	Do.	Do.	31·7	21·5	76
Nognoor Healthy	3,000	Do.	Do.	35·0	21·5	76
Nognoor Spiked	2,900	Do.	Do.	35·0	21·5	76
Uduparani	3,050	Do. mixed with boulders	Do.	37·0	21·5	76
Aiyur	2,950	Do. with sandy loam	Do.	35·0	21·5	76
Jawalgiri	3,100	Disintegrated gneiss	Do.	35·0	21·5	75

Methods of survey.—Three different methods were employed in the surveys, and were selected according to the nature of the area to be surveyed. Reconnoitring survey was conducted in the Uduparani area, since the severe slopes and rugged undulations do not lend themselves to a survey by other methods. The plot-strip method was employed for Devarabetta areas, which comprise continuous and practically uniform growth of sandal. The group system of surveying was found most suitable for the Nognoor area, where the sandal growth is not continuous, but occurs generally in patches. The manurial plots at Aiyur and Jawalgiri have been surveyed by the plot method.

The frequency and intensity of occurrence of each species of tree and shrub has been determined in all areas. The occurrence or the absence of a particular species has been broadly classified under the following heads :—

(1) Significant absence or diminished occurrence (Table IV);
(2) exclusive presence or significant preponderance (Table V);
(3) dead or coppiced stumps and lantana (Table VI).

DISCUSSION.

The differences found between healthy and diseased areas are very striking and suggestive. Diseased areas are characterised by a complete absence or diminished occurrence of certain types of flora

like *Barleria buxifolia*, *Cippedessa fruticosa*, *Dodonea viscosa*, *Breynia rhamnoides*, etc., while the preponderance of certain species of plants in healthy areas lends significant support to the theory that disease resistance in the sandal plant is controlled by particular types of host-plant. The high percentage of coppiced and dead stumps of host-plants, presumably exploited for fuel, found in diseased areas is very significant and supports the observation made in the laboratory that infected sandal succumbs to the disease more rapidly in absence of a host-plant.

The frequent association of abundant lantana with diseased areas led to the belief that it had some bearing on disease incidence. The surveys have confirmed this, which is placed on a quantitative basis by Table V ; but the exact value of this plant must remain a matter for future investigation. The rapid spread of lantana in a given forest area is invariably the result of either indiscriminate exploitation of the stock or frequent and severe fires, both of which result in opening out the forest and favour the growth of lantana. In other words, the sandal stock in the area suffers a change from deep-rooted and sturdy host-trees to surface-feeding bushes of doubtful host-value like lantana, *Acalypa Indica*, and others.

The following table connects the diseased areas so far surveyed with a significant absence or diminished occurrence of the following species of plants.

TABLE IV.

Name of Plant	Relative concentration of species in areas	
	Healthy	Spiked
Asparagus racemosus	71	17
Atylosia albicans	243	26
Barleria buxifolia	30	0
Breynia rhamnoides	204	4
Bridelia retusa	68	3
Canthium didymum	82	41
Cipadessa fruticosa	24	0
Cudrania Javanensis	15	0
Dioscorea oppositifolia	164	49
Dodonea viscosa	603	253
Ehretia buxifolia	70	31
Erythroxylon monogynum	124	68
Holarrhena antidysenterica	18	0
Memecylon edule	229	26
Pittosporum floribundum	104	0
Scutia Indica	116	43
Toddalia aculeata	148	52

The following table connects the diseased areas so far surveyed with an exclusive presence or a significant preponderance of the following species of plants.

TABLE V.

Name of plant	Relative concentration of species in areas	
	Healthy	Spiked
Acacia pennata	5	153
Acacia sundra	0	27
Atalantia monophylla	3	135
Clausena willdenovii	22	136
Lantana camara	284	4747
Limonia acidissima	0	6
Phyllanthus polyphyllus	14	375
Pterolobium Indicum	0	18
Strobilanthus kunthianus	78	169
Triumfetta rhomboidea	6	71

TABLE VI.

Locality	Dead trees		Lantana	
	Healthy	Spiked	Healthy	Spiked
Devarabetta	32	143	355	4787
Nognoor	41	134	284	4747

One of the most striking observations is the constant association of agricultural operations with the primary site of the first disease attack. In the case of every one of the diseased areas so far investigated there has not been a single exception. Artificial interference with virgin areas by cutting down the host-plants associated with sandal has been responsible for rendering it susceptible to disease, new outbreaks of which have always taken place in areas close to agricultural fields or colonies; but we are still far from tracing the ultimate origin of the infective principle.

SUMMARY.

1. The extent to which sandal is dependent upon host-plants for performing its useful physiological functions is indicated.

2. An ecological survey of the sandal-bearing areas in North Salem has been conducted chiefly to determine the influence of associated hosts on the susceptibility or resistance of sandal plants to spike-disease. These surveys are being extended to other types of forest in Coorg and Madras.

In conclusion, our thanks are due to Mr. J. E. M. Mitchell, District Forest Officer, North Salem, for the kind interest he has taken and for the facilities given us in conducting the survey.

Department of Biochemistry,
Indian Institute of Science,
Bangalore.

[Accepted, 29–6–31].

PRINTED AND PUBLISHED AT THE
DIOCESAN PRESS, POST BOX 455,
VEPERY, MADRAS—1931. C2476.