THE SPIKE DISEASE OF SANDAL

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Host Plant, the Fundamental Centre of Interest

THE sandal plant is influenced by its associated host plants with regard to its (*a*) growth, (*b*) seeding, (*c*) heartwood formation and (*d*) resistance to insect attack and spike disease.

Experimental and ecological evidence has been obtained to support the view that at no stage of its life can the sandal plant afford an independent existence with a normal functioning of all the above physiological activities.

The associated host plants, therefore, constitute the fundamental centre of interest, whatever be the line of approach, particularly in a study of the problem of spike disease.

It is well known that, generally, the physiological condition of the plant determines its predisposition to disease or insect attack, and this condition, in the case of the parasitic sandal, has been found to be influenced by its host plants.

The variety and quantity of insect fauna infecting a sandal, therefore, depends upon the floristic composition of the host group nourishing the plant.

Specificity of Association of Insects in Relation to Specific Host-Sandal Combination

Entomological collections of Mr. Chatterjee lend support to the above statement. The specificity of association of certain species of insects with certain definite host-sandal combinations has been established.

The practical significance of this discovery is realized if attention is called to the fact that the composition of the sap of sandal could be controlled through a judicious choice of host plants so as to render the sap distasteful or repulsive to certain classes of insects and possibly to vectors of disease, yet conclusively undetermined.

Types of Immunity

Disease-transmission studies under controlled conditions have revealed the existence of two types of resistance among sandal plants—(*a*) Autogenic resistance exhibited by certain plants which is largely independent of the nature of the associated host plant, (*b*) Acquired resistance, built up by the sandal if certain species of hosts and certain conditions of environment are provided.

Ecological evidence also lends support to the existence of both types of sandal plants. Strains of sandal inherently resistant to disease are often encountered in heavily-spiked areas, and with regard to the other type of resistance, floristic surveys have shown that the incidence and spread of disease is dependent upon the floristic composition of the area.

The discovery of these factors of disease-resistance among sandal plants constitutes an advance of great practical importance, as these facts are helpful in the establishment of sandal forests with resistant stock, reinforced by hosts known to impart immunity to sandal.

Two such areas have already been started in North Salem.

Haustorising Capacity—A Guide to Resistance

The property of autogenic resistance has been correlated with a high haustorising capacity and a comparatively large root system in the seedling stage of the sandal, thus affording a useful and practical guide to the selection of resistant strains. Attempts are now being made to discover a simpler morphological index easily recognisable in the seed itself.

Among the host plants through which sandal acquires relative immunity, are *Cassia siamia*, *Casuarina*, *Melia indica*, *Murraya*, *Koenigii*, *Dodonea viscosa*, *Semicarpus aancardium*, *Ficus bengalensis*, *Sarcostemma brevistigma*, *Ruta graveloens*.

Resistant and Susceptible Hosts

Among the host plants which have been found to render sandal particularly susceptible to disease are *Acacias* in general, *Pongamia glabra*, *Lantana camara*, *Cajanus indicus*, *Divi divi*, *Ocimum sanctum*.

It is obvious that the flora associated with sandal areas could be divided into two groups: (1) those which impart disease resistance to sandal and (2) those which render it susceptible to disease. This classification can be based either upon (1) direct experimental evidence or (2) indirect evidence based on ecological surveys.

The practical knowledge gained through both these sources has been utilised in the opening of regeneration plots in North Salem. Confirmation of the "susceptible" character of *Pongamia* and *Cajanus indicus* has already been obtained under sylvicultural conditions at Javalgiri.

Artificial Transmission

Artificial disease transmission through grafts constitutes an extreme type of infection, and a plant resistant to this operation would naturally tend to approach a strain possessing perfect and unqualified immunity. In the course of transmission studies, several such types have been obtained and these have been utilised for stocking an area at Javalgiri.

Grafts do not always take; organic fusion of the graft with the operated stock is necessary for effective transmission of disease. Sometimes the disease does not manifest itself in spite of intimate fusion, sometimes the graft is unsuccessful and in yet other instances the graft is thrown out by vigorous callous formation.

Resistance to Grafting in Relaltion to Environment

These laboratory findings have found confirmation under sylvicultural conditions. At Javalgiri about 80 per cent. success was obtained with regard to disease-transmission through grafts, while two similar operations at Mahadeswarangudi area have resulted in a complete failure of infection. The explanation to this remarkable and encouraging phenomenon is to be sought in the strikingly different floristic aspects presented by those two areas. Grafting under sylvicultural conditions, therefore, affords a useful technique for determining the susceptibility or resistance offered by environment to disease.

Root System of Host in Relation to Disease-Resistance

Among the other factors of environment which predispose sandal to disease, depth and extensiveness of the root system of the associated host play an important part.

Pot-culture studies have shown that, with a given sandal-host combination at any given age, the plants growing in bigger pots are more resistant to disease than those in smaller ones; the greater the volume of soil commandeered by the root system, the greater will be the nutrition made available to the parasite sandal.

The root system of the host plant which is parasitised by sandal may be looked upon as an extension of the root system of sandal itself. Deep-rooted hosts, in general, are beneficial to the parasite, not only with regard to its growth but also in building up immunity to spike.

The soil profile studies which have been made in this connection have revealed that spike areas are characterised by a poor root system both as regards depth and intensity.

In the choice of host plants for sandal, preference should be given to those species which possess deep and extensive root systems.

Sandal Itself, a Powerful Denuding Agent

In this connection the effect of sandal in restricting the regeneration of the root system of the host plant, has to be considered. This effect becomes pronounced when the parasitism on the host is heavy. In other words, the importance of recognising sandal as a powerful denuding agent is apparent.

Observations show that the primary attacks of spike have always occurred in places where the sandal stock is thickest and where the major hosts are either dead or dying. Overparasitism should, therefore, be strictly avoided in the sylviculture of sandal. Regeneration of the parasite should be controlled and a judicious thinning of sandal, having regard to the availability of host plants, should be worked upon as a recognised sylvicultural practice. Other plant parasites in the area should be systematically eliminated, since their presence would tax the nutritional resources of the environment.

Parasitised Hosts do not Stand Coppicing

Pot-culture studies have shown that sandal plants, when deprived of their host plants, succumb to the disease quicker. Host plants, parasitised by sandal on coppicing, rarely, if ever, put forth shoots. Field observations at Nognoor and Thalli points to the same conclusion.

These observations have a pertinent bearing on the sylviculture of sandal. No exploitation involving the deprival or weakening of host plants should be encouraged in sandal-bearing areas. All the host resources of the area should be conserved and consolidated for the vigorous and healthy growth of the parasitic sandal.

Masking of Disease

Experimental transmissions have shown that a sandal plant kept continuously under shade is more susceptible to disease than a corresponding one kept exposed to the sun. The "shade" plants take on grafts with a higher percentage of success and succumb to the disease in greater numbers. This lends experimental support to the observations of Rao Bahadur K. R. Venkataraman Ayyar who has always held that plants "under suppression" are predisposed if not actually infected. On exposure to the sun, these plants manifest the disease symptoms;

and the "shade" plants grafted with disease tissue behave in essentially the same manner with the bursting of new buds in response to the stimulus of sunshine.

"Suppression" or "shading" of young sandal should, therefore, be strictly avoided in the sylviculture of sandal.

In the course of transmission studies, it has been found that some sandal plants mask the symptoms of disease for long periods. In such cases defoliation of the plant has helped in forcing out the symptoms of spike. The plant, during the period of "mask", puts on girth and height.

Under sylvicultural conditions also this phenomenon of masking has been observed. In every infected area dozens of such plants may be found; in Manchi, for example, about 20 per cent. of the stock in the area were found to have been already infected.

Pollarding, an Important Technique to Force Out Symptoms

Sandal plants which thus mask the symptoms, constitute the sources of infection, since it has been shown by experiment that the disease can be transmitted to other healthy sandal plants by grafting some of their tissues.

Eradication of "spike" would not, therefore, be complete unless such sandal plants masking the disease are also eliminated. Non-removal of such apparently healthy sandal plants has been mainly responsible for the successive recrudescence of disease in an area, often in epidemic proportions.

In any scheme of eradication of spike, therefore, it is essential that pollarding should be adopted as a means of detecting "masking" trees. In the Manchi and Galigattam spike areas, this useful technique has been put into operation.

Disease Localised and Ringing Prevents Further Spread

Laboratory experiments have shown that the disease is localised in the initial stages of infection and that the transport of the casual entity to other parts of the plant from the site of infection is slow. Ringing at the right place and at the right time will prevent the spread of disease to other organs of the plant and save the tree from spiking.

The practical application of this information in the control of spike is limited by the fact that under sylvicultural conditions one does not know the site of infection.

During the operation of pollarding, however, it is possible that fortuitous decapitation of virus-infected branches may lead to elimination of infective organs and save the rest of the plant.

Season of Infection

It has been definitely ascertained that the actual infection occurs during April and May, which corresponds with the period when scar and other injuries are intensively inflicted on the sandal plant through some agency yet undetermined.

Season of External Manifestation of Symptoms

The symptoms of spike tend to manifest themselves on infected sandal plants during the season which corresponds with the vegetating period of sandal. In April, May and June, under the stimuli of moist-heat and sunshine, the disease manifests itself with the growth of the new flush from the dormant buds.

This information is very useful in fixing the season during which a vigilant watch has to be kept over sandal-bearing areas when fresh attacks may be expected in large numbers.

Shift of Season

Shift in the season of maximum disease incidence, may occur due to natural causes, which result in forcing out new flush in sandal plants. Forest fires and browzing by herds are the two main causes which effectively affect the period. The season during which fires occur is known to forest officers, and soon after its occurrence the epidemic should be looked for.

Primary Attacks Associated with Denuded Spots

Primary site of attack, so far as our present observations indicate, are characterised by marked changes in floristic composition, the change always accounting to a degradation towards the scrub xerophytic type of vegetation.

Deep-rooted species are replaced by shallow-rooted and deciduous shrubs of the lantana type, thus rendering moisture and nutrients from deeper layers unavailable to sandal.

This degradation is often found to be the combined result of exploitation, fire, over-parasitism, grazing and other denuding factors.

Effective measures for the protection of these denuding agents, should be laid down and rigidly enforced.

Lantana and Spike Disease

The frequent association of lantana with spike trees has led us to believe that it has some relation with spike disease. Laboratory experiments have shown that lantana is one

of the plants which renders sandal susceptible to disease. The more serious aspect of lantana is its aggressive spread with the gradual elimination of all useful species in the area. Its growth renders the soil toxic to most other plants which die in course of time. The ease with which lantana catches fire during the hot weather renders it a dangerous source of combustible material, and consequently the cause of frequent fires which accelerate the denudation of the area. Bird-life becomes scarce in lantana areas which proportionately encourages an abundance of insect fauna and possibly an increase in the concentration of the vectors of spike disease.

Elimination of lantana is a problem of great importance not only from the point of view of spike disease but also from the view-point of general sylviculture.

Elimination of Lantana Effects Remarkable Ecological Changes

It has been found that keeping down lantana artificially has a marked influence on reducing the incidence of disease, as found in Cairn No. 53, Observation area. This fact is due to the circumstance that continual weeding out of lantana has enabled other beneficial species to come up, and the ecological change that has been effected in the area during a period of seven years was remarkable.

The survey has revealed that, out of the 57 species of plants occurring in the lantana-free area, 21 are exclusive to the plot and are entirely absent from the lantana-infested area ; with regard to the other species occurring in both plots, they decidedly preponderate in the lantana-free area, where one cannot fail to notice that the plot has been well stocked not only with sandal but also with host trees.

This is a striking instance where, through human effort, a restoration of the deciduous high forest type of vegetation has been effected through the simple operation of weeding out lantana and the practical bearing of this fact on the control of spike disease is quite obvious.

Haustorial Spread of Disease not a Serious Factor

Effective artificial transmissions through haustoria so far achieved does not exceed 8 per cent., and, therefore, under sylvicultural conditions the spread of disease through roots is possibly very small. The secondary spread of disease is in consequence largely effected above ground through some agency, yet to be identified.

In the practical control of disease, therefore, factors operating above ground demand relatively more serious consideration.

Arsenical Preparations to Combat Spike

Effective removal of the sources of infection should be the immediate objective so far as diseased areas are concerned. Application of Atlas and other arsenical preparations as prescribed by Dr. A. V. V. Iyengar, have been found to be most effective agents in rendering the causal entity in the entire plant innocuous. The arsenic does not appear to interfere with the valued essential oil in the heartwood.

Scars, a Measure of Disease Incidence

In the absence of any statistical information ragarding the relative abundance of insect fauna in the various observation areas, a study of the scars has been helpful in obtaining a comparative idea of their existence or activity with respect to sandal. Results indicate that the intensity of attack on sandal, as measured by scars, is roughly proportional to disease incidence.

A Practical Scheme for Disease Control

Methods of disease control are necessarily preventive in nature, since there has been, so far, no instance of a plant recovering from spike. The root stimulation and injection experiments which were in the main intended to cure the disease, gave negative results. Even if a certain constituent should, in the course of future investigations, prove an effective cure for the disease, the practical application of the discovery would be beset with insurmountable difficulties. It would be well nigh impossible to deal with every diseased sandal plant by injecting the chemical, when large areas of spike as obtained in practice are encountered.

In considering methods of prevention, we have to take cognizance of the fact that the sandal occurs in widely scattered areas and grows under different conditions. The methods of control in consequence will have to be modified in accordance with the nature of the area. The following is an attempt at classification of sandal areas from a sylvicultural point of view.

In devising methods of prevention and remedy the following five kinds of sandal-bearing areas merit consideration :—

(*a*) What are the precautionary measures to be adopted in healthy areas, at present, far removed from sources of infection ?

(*b*) By what methods can we prevent a

further spread of spike into healthy areas which happen to lie in close proximity to sources of infection?

(c) What are the operations necessary to prevent a predisposed area from succumbing to disease?

(d) What is the most effective and economical methed of dealing with spiked areas?

(e) What is the best way of regenerating new sandal areas, which will ensure its freedom from "spike"?

Attention has been called to the fact that the primary sites of attack are always associated with denuded areas where a visible change in floristic coposition is effected. Prevention of this change would naturally constitute the best means of protecting healthy areas. Among the denuding factors which should be prevented from operating in any of the sandal areas, are:—

(1) Over-parasitisation due to a disproportionate regeneration and growth of sandal to be checked by judicious thinning.

(2) Other plant parasites of no economic value like loranthus, viscum, opilia, etc., which should be systematically eliminated from the area. These parasites as indicated before, deplete the nutritional resources of the environment.

(3) Exploitation of timber and fuel from sandal-bearing areas should either be totally avoided or scientifically controlled.

(4) All possible recognised methods of fire control should be rigidly enforced.

(5) Lantana and other aggressive weeds should be kept down, and open areas which might be invaded by these species may be planted up with some useful species.

(6) All species showing symptoms of 'spike', *e.g.*, *Z. œnoplia*, *Dudonea viscosa*, *Jasminum*, etc., should be promptly weeded out.

Other predisposing factors which have also a bearing on the sylviculture of sandal should be eliminated and the sandal plants should be enabled to build up resistance to disease. In this conection, the following suggestions are offered:—

(1) If afforestation of the area is contemplated, deep-rooted and "resistant" host plants, indigenous to the country, may be introduced into the area.

(2) "Shading" or suppression of sandal plants should be strictly avoided.

The above suggestions apply particularly to (*a*) and (*b*).

With regard to (*c*), where the ecological change has already been initiated or completed, a reversal of the conditions to the original state constitutes the most rational means of checking the incidence and spread of spike.

The main problem in such an area would involve:—

(1) The elimination of lantana and other shallow-rooted and aggressive species invading the area;

(2) the encouragement of the deep-rooted indigenous species to come up either naturally or through sowings. In this connection, attention may be called to the remarkable ecological change that has been artificially brought about in Cairn No. 53 at Javalgiri;

(3) a partial thinning of sandal plants may be effected to reduce the sandal-host ratio and to cut down competition for the available nutriment in the area;

(4) "spike"-bearing weeds should be systematically eliminated;

(5) fire protection, which might otherwise lead to further degradation of the area, should be enforced;

(6) in the case of sandal plants which look predisposed or suspicious, masked symptoms should be forced out by pollarding the tree. If, subsequently, the plant remains healthy, it would establish that the area is free from disease; if, on the other hand, the plant manifests the disease symptoms, it is always safe to assume that every sandal in the area is infected. A wholesale pollarding should generally be adopted as a routine.

Areas coming under the group (*d*), should first be treated in the following manner:—

(1) Immediate effective elimination of 'Spike' plants should be the first operation. The application of arsenical preparation have been very useful in this connection.

(2) Other sources of infection like (*a*) 'masked' sandal trees, (*b*) weeds suffering from spike and (*c*) the viruliferous vectors whose existence has been suspected but not experimentally established, should be considered.

The area may be then treated in exactly the same manner as if it were (*c*).

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