and contained wings but no seedcoats, except in longleaf. Why seedcoats developed in longleaf cones is unknown. Pollination was previously considered necessary for seedcoat development, though the seedcoat is not a product of fertilization. None of the longleaf seeds in unpollinated cones were filled.

Overall cone lasses were significantly higher for the unpollinated treatment than for controls in all species (Table 1). Abortions ranged from 42 to 70 percent for pollinated cones and from 67 to 96 percent for unpollinated cones. Differences among clones were also significant for all species, and the clone X treatment interaction was significant for all species except longleaf.

When clones that aborted all unpollinated cones were excluded from consideration, however, losses from unpollinated cones and from wind-pollinated controls were not significantly different for loblolly and slash pines. In loblolly, 68 percent of the unpollinated cones and 49 percent of the pollinated cones aborted. In slash, losses were 44 percent for unpollinated cones and 40 percent for controls. A similar statistical comparison could not be made for the other two species since only one clone of each did not abort all unpollinated cones.

In all four species, insect depredations accounted for nearly all abortions of pollinated cones and for more than half the abortions of unpollinated cones. Possibly the bags protected the unpollinated strobili from some insects. The main insects observed were seed bugs (Leptoglossus corculus SAY and Tetgra bipunctata H.-S.), tip moth (Rhyacionia frustrana COMSTOCK) and Diorgctria spp. Insect losses occurred primarily during early spring when strobili were receptive and were usually indicated by discoloration at the distal tip of conelets. Abortions attributed to lack of pollination took place in early to midsummer and were distinguished by a browning of the scales at the proximal ends of conelets. Such damage was never observed on pollinated controls.

Conclusions

In the four southern pine species tasted, the ability to develop mature cones from unpollinated strobili appears to be a clonal trait since some clones consistently abort all such strobili. Lack of pollination resulted in increased abortions in this test but should not be a serious problem within the species' natural range since adequate pollen clouds are typically produced in orchards or supplied from surrounding stands.

A far more serious threat to developing strobili is insect damage, which caused all abortions of pollinated cones and most abortions of unpollinated cones in this test.

Summary

Twelve of 18 loblolly (Pinus taeda), 3 of 5 slash (P. elliottii) 1 of 7 shortleaf (P. echinata), and 1 of 5 longleaf (P. palustris) clones developed mature cones but no filled seed from unpollinated strobili. Although abortions were more common for unpollinated conas than for pollinated cones, insect damage is apparently a much more serious threat to developing strobili than lack of pollination.

Key words: Cones, conelets, pollination, Pinus.

Zusammenfassung

Bei Pinus taeda entwickelten 12 von 18 Klonen einer Samenplantage reife Zapfen, bei Pinus elliottii 3 von 5 Klonen, bei Pinus echinata 1 von 7 Klonen und bei Pinus palustris 1 von 5 Klonen. Bei unbestäubten weiblichen Blüten kam es zur Zapfenentwicklung, aber es konnten nur taube Samen geerntet werden. Die Zapfen aus unbestäubten Blüten wurden z. T. abgestoßen, d. h. in größerer Anzahl als diejenigen aus bestäubten Blüten. Als Hauptursache für den Zapfenverlust wird jedoch der Befall durch Insekten angesehen.

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A model relating needleless shoots and dieback in Pinus caribaea to strobilus production and climatic conditions

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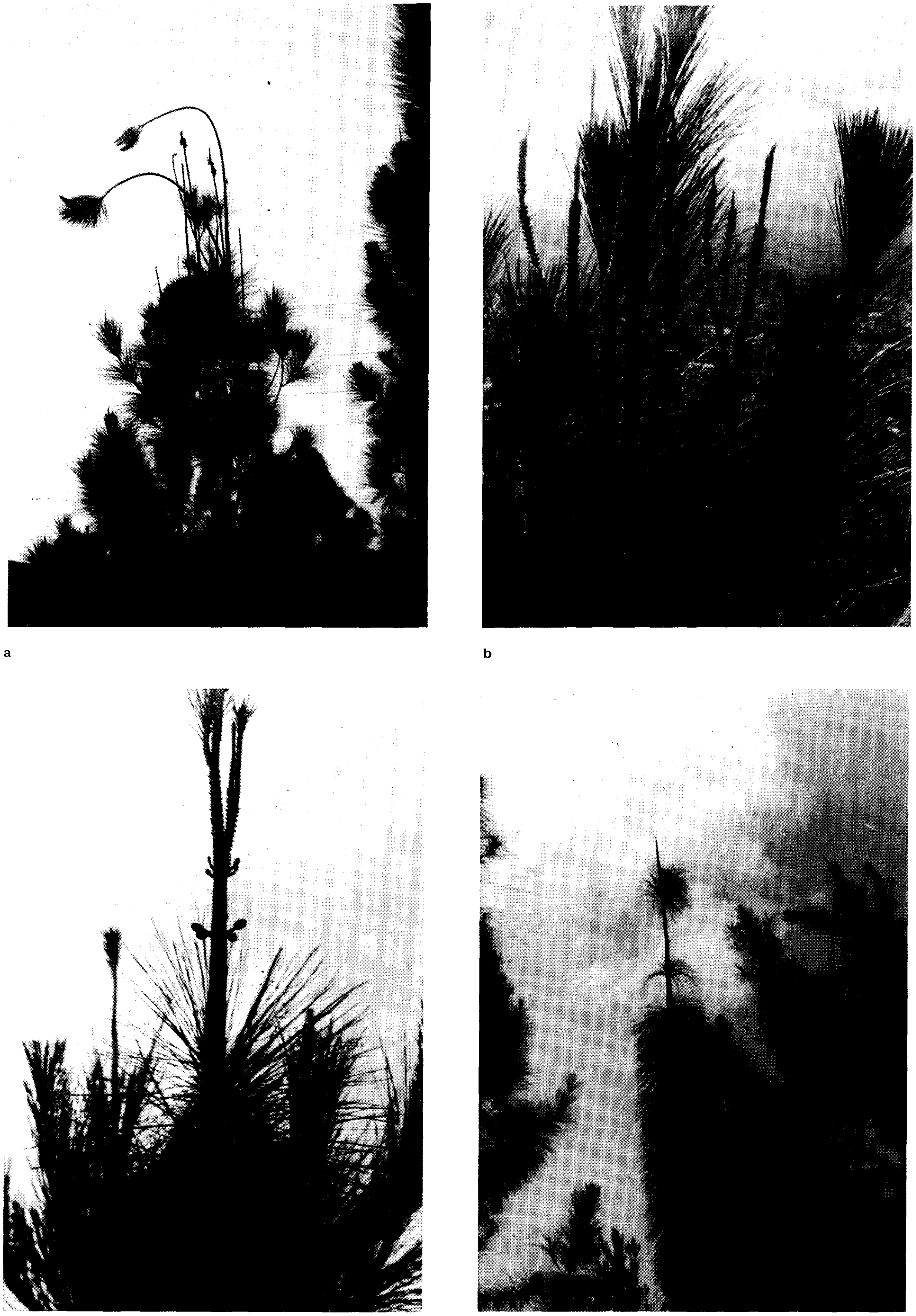
Introduction

Studies of Pinus *caribaea* (MOR)var *hondurensis* (BARR et GOLF) in Malaysia (SHIM, 1974; SLEE, SPIDY and SHIM, 1976) have indicated the species is not well suited to lowland regions of the country. The species exhibits abnormalities in both reproductive and vegetative growth. SLEE et al. (1976) considered the cause to be climatic and questioned the species suitability for other areas of the humid tropics.

It has recently been possible to examine plantings of Pinus caribaea in lowland regions of Kenya, Surinam, Trinidad and Venezuela. The results of these studies are reported here. Combined with results from the previous studies these have allowed a hypothetical model to be developed which relates the abnormalities found in the humid tropics to climatic conditions and in particular to the conditions controlling strobilus initiation and development.

The model is based solely on field observations allied with temperature and daylength regimes and not on physiological studies. Ideally detailed anatomical and physiological studies should be conducted. Such studies will necessarily involve international cooperation and will take con-



a b c d

Figure 1. — Needleless shoots on *Pinus caribaea* trees at Sungei Buloh, Malaysia. Pollen strobili are associated with the needleless shoots (in a and b).

siderable time. Meanwhile the planting programmes with *Pinus caribaea* planned for the humid tropics are so large that it is essential to produce guidelines as soon as possible. The model can be used to indicate regions to which *Pinus caribaea* may not be suited.

Development of the study

The unhealthy appearance of *Pinus caribaea* in lowland Malaysia has been noted by several authors (see SLEE *et al.* 1976). Initially the trees appear healthy but after approximately 3—4y in the field needle development on portions of the main or branch stems may be impaired. Affected portions are usually bare of needles. These needleless shoots may be several metres in length. Where needle failure is extensive dieback may occur or the shoots lose dominance, producing stem malformations ranging from minor kinks in the main stem to major basket whorls with complete loss of a main stem above the whorl. Malformations may be repeated several times on one tree, presumably because of successive periods of dieback. In other trees needle failures are confined to young developing shoots, which die whilst still short and are quickly replaced. Affected trees have a debilitated appearance *(Figure 1)*.

Commencement of needle failure on a particular tree apparently coincides with commencement of flowering of that tree. Inspections of young plantations showed strobili were always associated with the needleless shoots or were present on other shoots of the same age on the tree concerned.

The occurrence and development of *Pinus caribaea* strobili in Malaysia is abnormal compared with the pattern usual in Queensland, Australia, (SPIDY 1975), where the species grows vigorously and does not usually produce needleless shoots. In Malaysia pollen strobili occur higher in the tree and are less frequent than in Queensland. Pollen may be shed at any time of year (WHITMORE 1975). Shedding from a single cluster of strobili may be spread over several months rather than being completed within a two week period as is usual in Queensland. Pollen strobili are also often associated with the needleless shoots described above (KOZLOWSKI and GREATHOUSE 1970).

Tree health improves at high altitudes in Malaysia (SHIM 1974). This was verified in a recent study in which SLEE *et al.* (1976) examined a sample of trees at several different locations in both Peninsula and East Malaysia and classified each tree according to the degree of malformation evident *(Table 1)*. This gave an indication of the incidence of dieback at each location and permitted comparisons to be made between locations.

Procedure

In the present study plantations in lowland areas of several countries in the central tropics were examined using the procedure previously used in Malaysia. Plantations were examined and assessed at one location in Kenya, and two in each of Surinam, Trinidad and Venezuela. An additional plantation in Malaysia was also included. The trees assessed were generally aged between 7 and 11y, with one older plot aged 17y. The soils varied. In Kenya the plantation was on deep compact silty sand and the Malaysian soils at Labis were a sandy loam. Elsewhere the soils were sandy podzolics. Details of the locations, with altitudes and latitudes are given in *Table 2* in which the results of this study have been combined with those from the earlier study in Malaysia (SLEE *et al.* 1976).

The number of stems examined in each assessment was usually between 40 and 50 (including missing stems) with the extremes 25 and 67. On each stem the occurrence of deformities was noted and the stem classified either as unaffected or as slightly, moderately or severely affected according to the scheme detailed in *Table 1*. The proportion of stems in each category at each site was calculated in relation to the number of trees originally planted as some plantations had been thinned or had stems missing for other reasons. To facilitate comparisons each planting assessed in this and the previous study was given a point score based on the percentages of unaffected, slightly affected or moderately affected stems present. The percentage of unaffected stems was multiplied by 6, of slightly affected stems by 4 and of moderately affected stems by 2 and the total calculated for each assessment.

Table 1. — The classification scheme used to assess the effect of dieback on individual trees

Unaffected	A normal tree exhibiting no evidence of dieback
Slightly affected	Tree has either:
	Dead branch tips present or branch tips present on which normal needle development has not occurred
	or
	Irregular needle development present, i.e. deformed needles present or short (single flush) sections of branches or main stems bare with well developed needles above and below
Moderately affected	Exhibits one or two occurrences of forking, kinking or minor basket whorl formation or a combination of these
Severely affected	Exhibits any of the following features:
	An abnormally long leading shoot on which no regular needle development has occurred
	A major basket whorl
	Three or more forks, kinks, or minor basket whorls or a combination of these
	Badly suppressed, thin crown, needle dieback and stem deformities

n.b. a basket whorl is a whorl of branches at one position on the main stem containing thicker and more numerous branches than in a normal branch whorl. A major basket whorl has large or very large branches and the main stem changes diameter noticeably at the whorl position. A minor basket whorl has branches of approximately normal size and only a slight change in main stem diameter.

Results

Trees of *Pinus caribaea* in Surinam, Trinidad and Venezuela, were not as badly affected by dieback and deformities as trees in Malaysia. Although needle failure was present in these countries the lengths of shoots affected were shorter than in Malaysia and the long (2—3 m) needleless shoots, common in Malaysia, were very rare. The percentage of stems unaffected or only slightly affected by dieback ranged from 19—30 in the plots in Malaysia. The range in Venezuela was 23—41, in Trinidad 27—44 and in Surinam 36—39 *(Table 2)*.

The results of the two studies have been combined and summarized in *Table 2*, using the point score system. The score gives a measure of the amount of deformity present in a stand; a low score indicating a high incidence of deformity. The lowland plots in Malaysia had scores between 118 and 204. Malaysian plots at intermediate altitudes (350 to 500 m) were superior, with scores between 246 and 336.

Table 2. — Summarized results of the assessments of dieback and deformity over a wide range of latitudes and altitudes in several tropical countries.

Plot	Country	Point score	% of trees severely affected or dead	% of trees slightly or not affected	Latitude (° N)	Altitude (m)
S. Buloh	Malaysia	118	69	20	3	10
Labis	Malaysia	134	66	24	3	30
Kolapis	Malaysia	164	59	24	5	30
S. Buloh	Malaysia	176	56	27	3	10
Gum Gum	Malaysia	184	49	30	6	30
Sibuga	Malaysia	190	40	28	6	30
Labis	Malaysia	194	54	29	3	30
Sungei Sapi	Malaysia	194	33	19	6	50
Timbang	Malaysia	196	34	23	6	100
Tempasuk	Malaysia	200	36	19	7	100
Tempasuk	Malaysia	204	32	19	7	100
Cumuto	Trinidad	214	45	27	10	10
Cachipo	Venezuela	214	37	23	8	70
Cumuto	Trinidad	240	40	31	10	10
Blakawatra	Surinam	256	40	36	6	10
Coeswijne	Surinam	278	39	39	5	10
Uverito	Venezuela	280	30	41	8	70
Piarco	Trinidad	304	36	44	10	10
Sook	Malaysia	246	30	43	5	350
Sook	Malaysia	270	28	35	5	350
Tapah Hills	Malaysia	306	28	47	4	500
Tapah Hills	Malaysia	336	27	57	4	500
Kwale	Kenya	388	29	63	4 (° S)	400
Kundasan	Malaysia	408	29	68	6	1300
Ranau	Malaysia	484	4	75	6	800
Sospodon	Malaysia	494	13	80	6	1400

Lowland plots in Surinam, Venezuela and Trinidad, with scores between 214— and 304, were also superior to the lowland Malaysian plots. The highland plots in Malaysia, and the plot at Kwale in Kenya, were superior to all others (388 to 494).

The development of the model

The occurrence of the needleless shoots and the consequent dieback and deformities can be related to the temperature and daylength regimes controlling flower initiation and development. This has been done by means of a model to show how variations in temperature and daylength can produce a range of effects from purely vegetative growth with no flowering to restricted vegetative growth and massive deformity.

Before defining the model in detail it is necessary to outline the process of strobilus formation and development in *Pinus* and to indicate how failures in strobilus development may result in the formation of the needleless shoots. The primordia in *Pinaceae* are initially undifferentiated and may become either vegetative shoots or strobili (Pharis 1976). Thus Mergen and Koerting (1957) with Slash Pine and Eggler (1961) with four southern Pines could not distinguish the early stages of strobili from vegetative primordia. Differentiation of primordia to a vegetative or floral form is determined by subsequent environmental conditions.

If environmental conditions inducing differentiation of floral primordia continue for a long period then production of vegetative primordia will presumably be restricted. In *Pinus* the pollen strobilus replaces a vegetative short shoot and the seed bearing strobilus replaces a long shoot (Doak 1935). Thus stems of *Pinus* formed under conditions favourable for differentiation of floral primordia will carry pollen strobili instead of vegetative short shoots. In the model it is suggested the needleless shoots of *Pinus caribaea* carry floral primordia. The frequent occurrence of pollen strobili on needleless shoots and occasional complete coverage of such shoots by strobili (Kozlowski and Greathouse 1970 and *Figure 1)* supports this suggestion. Under the same conditions long shoots may be replaced by female strobili.

Many primordia on the needleless shoots fail to develop. Pharis and Morf (1972) and Sweet (1973) have indicated changes in daylength and temperature regimes are essential for development of floral primordia to anthesis and a temperature decline is particularly important (Pharis 1976). When the necessary conditions are not experienced the primordia abort. It is suggested that needleless shoots are formed when the temperatures and daylengths stimulate differentiation of floral primordia but subsequently climatic conditions do not change sufficiently to allow development of these primordia.

For simplicity of presentation the model takes no account of existing individual differences within *Pinus caribaea.* Between 19 and 30% of the trees in Malaysia are not severely affected by dieback *(Table 2).* Thus although the model refers to particular daylength and temperature regimes as critical, these have general application only and some trees will not conform precisely.

The model defined

Phase 1 — The Period of Juvenility

There is an initial phase in the development of a tree when growth is entirely vegetative. Provided environmental conditions, including moisture status and soil fertility, are suitable, vigorous vegetative development occurs. No flowers and no needleless shoots are produced during the juvenile phase.

Phase 2 — The Period of Fertility

After passing through the period of juvenility the trees enter the condition known as "ripeness to flower". This condition lasts for many years and growth may be vegetative or reproductive. The model relating the growth which occurs in *Pinus caribaea* to a temperature × daylength control is shown diagrammatically in *Figure 2.* In the model growth is vegetative unless short day and high temperature conditions are experienced.

In *Figure 2* the relationship between mean monthly temperature and mean monthly daylength has been depicted graphically as subdivided into two zones. They type of growth which occurs at a particular time is determined by the zone which contains the graphical plot of the temperature and daylength regimes at that time. Thus if the plot is in Zone A vegetative promordia are differentiated and if the plot is in Zone B floral primordia are differentiated. The boundary between the zones indicates postulated critical values for the temperature × daylength interaction which controls the differentiation of floral primordia. The suggested relationship between temperature and daylength is linear over the range 23.5° C at 11 h to 28° C at 13.25 h.

Development of floral primordia to anthesis is not possible unless the regime changes from Zone B to Zone A following differentiation. Once floral primordia have commenced development temperatures need to fall or daylength to increase for development to proceed. If this does not occur the developing floral primordia generally abort resulting in bare stems. In *Figure 2* this occurs when the plot of the regime remains in Zone B.

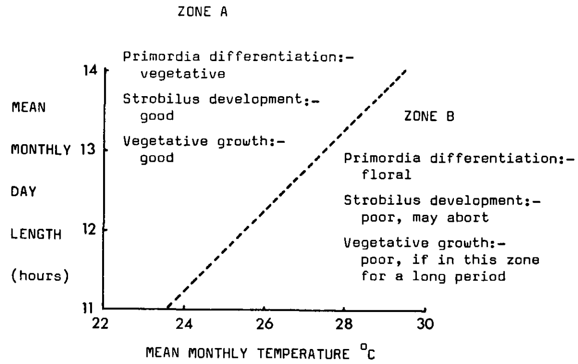


Figure 2. — Diagrammatic representation of predicted performance of *Pinus caribaea* in relation to mean monthly daylength and temperature.

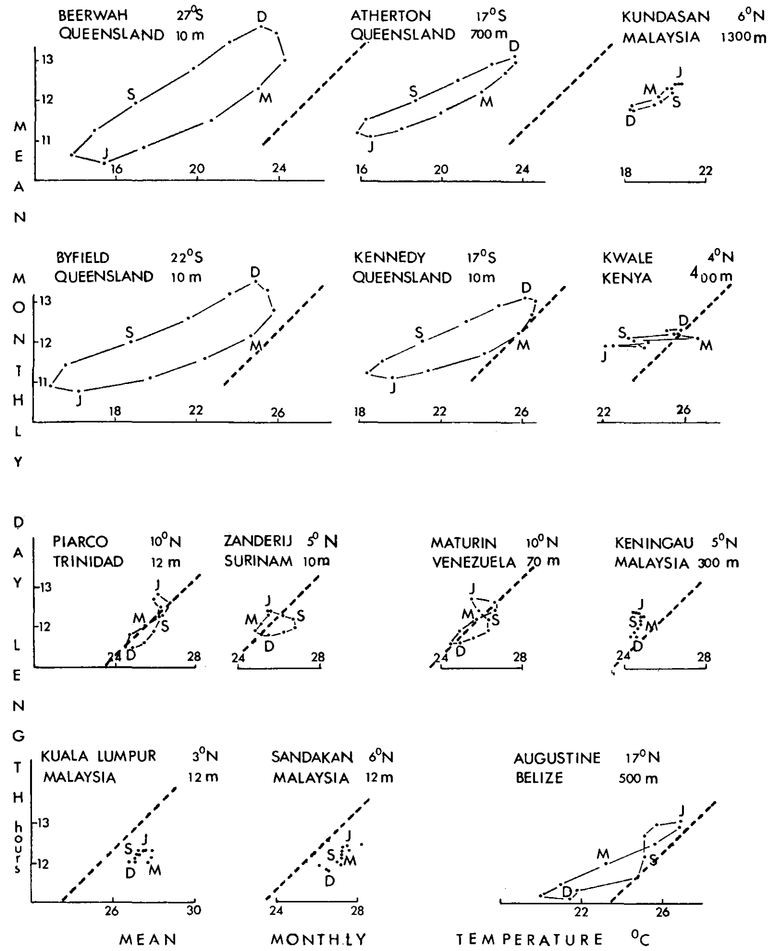


Figure 3. — Diagrammatic representation of the mean monthly daylength — mean monthly temperature regimes for various centres in relation to the zones of the model. The dotted line is the dividing line between the zones. Data are shown for each month, D = December, M = March, S = September and J = June.

Data from:

World weather records 1951—1960. E.S.S.A., U.S. Dept. of Commerce, Washington D.C. (1966);

Tables of temperature, relative humidity and precipitation for the world. Meteorological Office London H.M.S.O. (1967);

Hydrological records of Sabah to 1968. Drainage and Irrigation Dept. Hydrol. Div., Kota Kinabalu, Sabah. (1968);

Dyson pers. comm. and Greaves pers. comm.

In summary therefore growth of *Pinus caribaea* is vegetative unless the plot of the prevailing climatic regime in terms of daylength and temperature enters Zone B of *Figure 2.* In this zone floral primordia are initiated but these only develop if the plot subsequently moves to Zone A. If this does not occur the primordia abort and shoots remain bare.

The relationship of the model to field conditions

The juvenility phase was readily apparent in all areas visited. During this phase vigorous vegetative development occurs in young trees provided soil fertility and moisture conditions are favourable. Growth in the year following planting may be slow as the trees become established but subsequent height growth increments of 2 m per annum are common and may reach 3 m on fertile sites. The trees are healthy with good foliage density and there is an absence of flowers and needleless shoots.

The transition to flowering condition, indicated by the presence of strobili, occurs after about three to four years in the field, but there is considerable variation among individual trees and possibly between site conditions and seed sources. Consequently the cause of the change is difficult to determine. Neither age nor size appears to exert a strong control. Some trees carry strobili and needleless shoots in their third year in the field, whilst others only do so much later (seven years of age). Similarly some trees flower when only 2 m high but others may be 6 m high before flowering occurs.

The performance of *Pinus caribaea* in the field indicates the species does require high temperatures and short days for flower initiation. The species flowers well in the lowland tropics but not at high altitudes or latitudes (Lamb 1973, Shim 1974). Detailed examination of the temperature and daylength regimes for various regions in which the performance of *Pinus caribaea* is known *(Figure 3)* shows the critical levels quoted in the model to be valid for a wide range of conditions.

At high latitudes or altitudes (e.g. Beerwah and Atherton in Queensland, Australia and Kundasan in Malaysia) very little flowering occurs and there is very little needleless shoot production. The temperatures and daylengths at these centres *(Figure 3)* never reach the proposed critical levels for general flower initiation (i.e. the regime never enters Zone B of *Figure 2)* and growth in the field conforms to the model.

At Kennedy in Queensland (17^0 S) good flowering does occur. Here, the prevailing regime is only in Zone B in March *(Figure 3).* Differentiation of flower primordia presumably occurs at this time for anthesis follows in May and June. The species performance at Byfield in Queensland (22^0 S) is similar to that at Kennedy but flowering may be poor in some years. This also conforms to the model because the regime at Byfield does not enter Zone B *(Figure 3).* The years in which good flowering does occur at Byfield may have warmer than average conditions in the period February — March, which would bring the regime into Zone B of the model. At both Kennedy and Byfield the regimes are well within Zone A for much of the year and there are long periods when growth is vegetative with no differentiation of floral primordia. Needless shoot formation is rare at both centres.

Good flowering and very little needleless shoot formation occurs at Kwale in Kenya, at 4^0 S and 400 m altitude, where temperatures range between 22.1 and 26.6 but daylength change is very small *(Figure 3).* The temperature at Kwale is only above the suggested critical level (and the regime in Zone B) during March. Thus, as at Byfield and Kennedy, there is only a limited period during which flowering primordia are differentiated and there are long periods of purely vegetative growth.

Climatic records are available for Piarco in Trinidad, Zanderij in Surinam and Maturin in Venezuela, *(Figure 3),* all of which are centres close to the plantation areas in these countries. Data over two years are also available for Keningau, near Sook, in Malaysia *(Figure 3).* Flowering is good at these centres but needleless shoot production is also usual. For much of the year the climatic regimes are close to the postulated critical levels; thus small temperature and daylength changes could have important effects. Differentiation of floral or vegetative primordia could be intermittent or each could last several months. However, at all four centres, there may be a period of several months, during which the regime is in Zone A *(Figure 3).* During this period the primordia differentiated would be entirely vegetative. This lengthy period of vegetative growth may enable the trees to recover from the more serious effects of the reduced needle formation at other times. The degree of recovery would presumably be less in less vigorous trees, (i.e. those which are older or on fertile sites). Anthesis in Trinidad and Surinam occurs in February and March. This also conforms to the proposed model as the regimes at this time are in Zone A.

The temperature regimes in lowland Malaysia (Kuala Lumpur and Sandakan) are above the suggested critical levels throughout the year *(Figure 3).* Thus the regimes at these locations are in Zone B at all times. This presumably promotes year round floral primordia differentiation with inhibition of needle formation and also abortion of the developing floral primordia. Consequently there is extensive production of needleless shoots. The greater incidence of deformities recorded in lowland Malaysia therefore agrees with the proposed model. Further support for the model comes from Spidy's (1975) observations on the pollen strobili which do develop. The prolonged period of maturing and shedding of strobili within a single cluster indicates an absence of a strong control of strobilus development. This presumably reflects the uniformity of the temperature regime and the absence of acolder period or an increase in daylength.

The climatic regime at Augustine, Mount Pine Ridge, Belize, is of interest. This region has provided most of the seed material used for exotic plantings of *Pinus caribaea.* There is a similarity between the daylength $\times$ temperature regime of this region and those of regions where seed production of *Pinus caribaea* is satisfactory and needleless shoot production does not occur *(Figure 3).*

Thus the model generally explains the performance of *Pinus caribaea* in terms of flowering, needleless shoot production and the occurrence of deformities in Australia, Malaysia, Kenya, Surinam, Trinidad and Venezuela. Needleless shoot production appears closely related to the period of time the climatic regime spends in Zone B of *Figure 2.*

Discussion

The field observations with *Pinus caribaea* provide strong evidence of a high temperature $\times$ short daylength interaction controlling flowering in the species. There are some indications of similar control in *Pinaceae* in temperate regions. High temperatures enhance flowering in *Picea abies* and *Picea sitchensis* (Pharis 1976) and pollen strobili in *Pinus* are usually differentiated in late summer (Wareing 1958, Mergen and Koerting 1957 and Eggler 1961) when temperatures are high and daylengths are becoming shorter. MIROV (1956) and WAREING (1958) working with numerous American *Pinus* species and with *Pinus sylvestris* respectively, considered photoperiod had little control of Pinus flowering but took no account of a possible interaction with temperature. GIERTYCH (1967) has outlined indirect evidence of short day control of production of seed bearing strobili in *Pinus*, but also suggested the genus might react as long day plants in producing pollen strobili.

The genus *Pinus* is very widespread but absent from the humid tropical region. The interchangeability of vegetative and floral primordia may demand the genus inhabit areas with definite changes in the prevailing daylength or temperature regimes so the differentiation of floral primordia be restricted to a suitably short period of time. Changes may also be necessary to allow development of strobili to anthesis. These conditions are not found in the humid tropics and this may explain the absence of this genus from the region.

The wisdom of using *Pinus caribaea* in regions where it suffers extensive dieback can be questioned. Using the model as a quide the species appears to require a climatic regime with some temperature changes and to be unsuited to areas with short maximum daylengths and high mean monthly temperatures. In general *Pinus caribaea* appears unsuited to lowland areas within five degrees of latitude of the equator, but local variations of temperature need to be considered. For example, temperatures at Libreville in Gabon at lat. 0^0 23' N and 30 m altitude range between 24 and 27^0 C. Daylengths are almost constant and just over 12 h. Thus the regime would move seasonally between the zones and periods of both vegetative and floral differentiation would occur. The situation is similar to Trinidad and Surinam and on the basis of the model *Pinus caribaea* would suffer less dieback in this location than in Malaysia and the area may be climatically suitable for plantations.

The model is presently based solely on circumstantial evidence from field experience. Further studies are needed to verify and to fully define the controlling factors, both external (climatic) and internal (physiological).

Acknowledgements

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Abstract

Assessments of the incidence of dieback in *Pinus caribaea* (MOR) var. *hondurensis* (BARR et GOLF) in Kenya, Trinidad, Surinam and Venezuela showed the trees in these countries were affected to a lesser extent than trees in Malaysia.

Dieback of *Pinus caribaea* in the humid tropics originates from failure of needle development over a portion of the stem. The cause may be climatic. Temperature and daylength regimes may induce differentiation of floral primordia for long periods of time and vegetative short shoots and needles cannot be produced during these periods. The floral primordia may abort leaving affected stems bare of short shoots.

A model is proposed in which differentiation of floral primordia in *Pinus caribaea* is effected at high temperatures and short daylengths. On the basis of the model *Pinus caribaea* appears generally unsuited to lowland areas within 5^0 of latitude of the equator.

Key words: *Pinus caribaea*, shoot and needle development, flowering, climatic controls.

Zusammenfassung

In Malaysia zeigt *Pinus caribaea* var. *hondurensis* in Tieflagen, innerhalb von 5 Breitengraden beiderseits des Äquators partielle Schäden, indem sowohl der Haupttrieb als auch Seitentriebe teilweise absterben. Die Untersuchung zur Ergründung der Ursachen für dieses Triebsterben, die in Malaysia und zugleich in den zentralen Tropen in Kenya, Surinam, Trinidad unnd Venezuela durchgeführt wurde, ergab, daß *Pinus caribaea* var. hondurensis in Malaysia am stärksten geschädigt ist. Als Ursache für das partielle Triebsterben werden die Temperatur und die Tageslänge angesehen, die insbesondere die Bildung von Blütenprimordien für längere Zeit fördern, wodurch die Ausbildung von Kurztrieben und Nadeln verhindert wird.

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