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EFFECT OF PHOTOPERIOD ON ANNUAL GROWTH CYCLE OF TWO FOREST TREE SPECIES AT SEEDLING STAGE

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ABSTRACT

The seedlings of *Pterygota alata* and *Manilkara bojeri* were exposed daily to normal day length (ND), short day (SD) and long day (LD) conditions. Relative rates of extension growth were calculated under each treatment.

Under ND conditions, *Pterygota* plants assumed dormant condition from November to March with major part of season's growth occurring in August-September. *Manilkara* plants under similar conditions, continued to grow though the growth rates declined progressively and were of lower order during December-January.

Under LD treatment, *Pterygota* plants became dormant one month later and resumed growth about two months earlier than ND plants; SD conditions, however, brought about dormant growth at the same time as ND treatment but the growth was resumed as under LD plants i.e. about two months earlier than ND. *Manilkara* plants were induced to dormant condition both under SD and LD treatments and the period corresponded exactly with small growth rates under ND conditions.

It is concluded that these two species are by and large indifferent to LD and SD conditions and that the annual growth-cycle in nature is more under the changing influence of total sum of weather conditions rather than entirely on day lengths.

INTRODUCTION

The interaction effect of the various eco-edaphic factors on the growth and development determines very largely, the pattern of plant distribution in nature. In any scheme of plant introduction therefore, the correct evaluation of these factors is of utmost importance. Often, there are one or more factors which might be regarded as more important than others in the overall success or failure of plants in a particular environment. One such factor is the relative length of day and night effecting growth and development particularly in temperate regions where large differences appear during the different periods of the year. Whereas, annuals respond to unfavourable photoperiods by completing their cycle of growth and subsequent death, the perennials exhibit a state of dormancy and initiate fresh growth at the onset of favourable photoperiod.

Kramar (1936) found that the seedlings of white ash (*Fraxinus americana* L.), beach (*Fagus grandifolia* Ehrb.), black locust (*Robinia pseudoacacia* L. yellow poplar (*Liriodendron tulipifera* L.) red or sweet gum (*Liquidambar styraciflua* L.), white oak (*Quercus alba* L.), red oak (*Q. borealis maxima* Ashe.), post oak (*Q. stellata* Wang.) and loblolly pine (*Pinus taeda* L.) made more growth and grew later in the autumn when day light was supplemented by electric light to give a photoperiod of 14.5 hours. Short days (8.5 hrs) induced most of them to form dormant buds sooner than the normal day. Waring (1956) while reviewing the subject, pointed out that some species form dormant buds after a certain definite growth period even when they are illuminated continuously, Nitsch (1957 b) summarised all the information on the shoot growth reaction to photoperiod.

Tree species of the tropical regions and of the coastal areas in particular, are not subjected to so wide variations in the matter of day length during the various seasons. Though most of them exhibit a regular pattern of autumn and spring growth, many keep growing continuously. Nanda (1963) studied the extension growth of the three Indian species vide *Michelia champaca* L., *Kydia calycina* Roxb. and *Salmalia malabarica* (DC.) Schoft & Endl. and observed that the period of extension growth was prolonged under long days and shortened in short days.

In view of meager information of the growth response of tropical trees, it was considered worthwhile to investigate further. In the present study, the effect of day length on *Pterygota alata* (Roxb.) R. Br. (a conspicuously deciduous plant) and *Manilkara bojeri* (A. DC.) Lam (continuous growth habit) is reported.

MATERIAL AND METHODS

About half year old seedlings of the two species—*Pterygota alata* (Roxb.) R. Br. (Fam. Sterculiaceae) and *Manilkara bojeri* (A. DC.) Lam (syn. *Labramia* *bojeri* A. DC. Dub. ; Lam H. J. Blumea 4: 355, 1941) (Fam. Sapotaceae) were used in the present study. The former species is a native of Eastern India, and is distributed in India, Pakistan and Burma (Roxb. Fl. Ind. 1832 ; Hort. Beng. 1814). The plants attain a height of more than twenty meters. The later species is a very old introduction from Madagascar. Full grown plants are less than ten meters in height.

The plants were raised from locally collected seeds during July-August 1965 in 30 cm unglazed earthen pots having well mixed garden soil and farm-yard manure ; each pot containing one healthy seedling. The plants were allowed to grow under natural conditions upto 1st of March 1966 when the following three photoperiod treatments were started.

(*a*) short day (SD) with normal day length cut down to six hours.

(*b*) normal day (ND) with natural illumination under Calcutta conditions.

(*c*) long day (LD) with 18 hours of illumination (normal day length supplemented with artificial light obtained from flourescent and incandescent lamps to provide an illumination of about 200 foot-candles at the plant surface).

Plants were transferred to light and dark chamber at fixed timings. A preset time-switch controlled the light switches. There was no provision for the control of temperature except for the light-tight exhaust fans. In either of these treatments, there were twentyfive plants of each species. Their height measurements were recorded at periodic intervals from a fixed point near the soil surface to the base of the terminal unopened bud of the main shoot. As many as three to five plants had to be rejected during the course of the experiment either because of their uneven growth or development of lateral buds. The rate of stem elongation at any time was determined by dividing the difference between the log. values of mean consecutive height observation by the number of days.

EXPERIMENTAL RESULTS

The cumulative mean growth in height of the two species growing under ND, SD & LD at different times for the period between March 1966 to June 1967 is plotted in fig. 1. It is seen that the plants under ND, overtook in height those either under LD or SD, immediately a month or so after the beginning of the experiment. Plants kept in long days overtook those treated with short days just about two months after the onset of these

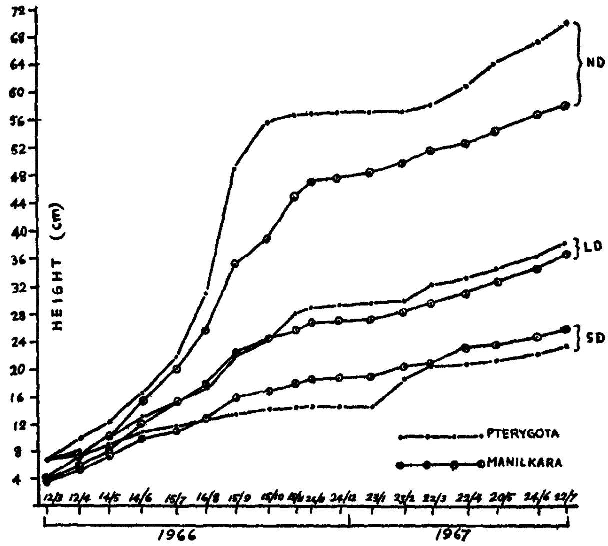

Fig. 1. Cumulative growth in length of the two plant species, *Pterygota alata* and *Manilkara bojeri* at different times under normal, long and short days.

treatments. The overall cumulative growth in height therefore, remained much superior under normal day conditions in both of these species right from the beginning. The growth curves in all these cases are sigmoid in nature. In figs. 2 & 3, the cumulative growth during each observation interval, is redrawn as percent of maximum growth taken as 100 in each case. The sigmoid nature of each curve is now more revealing.

(*i*) *Effect of normal days :* It would be seen that the cycle of annual growth differs considerably in the two species. Under normal days, the stem elongation in *Pterygota* stopped more or less completely from about the middle of November 1966 to about the end of March 1967 (about four and half months). The plants remained dormant during this period. The extension growth assumed linerity abruptly afterwards. *Manilkara* plants under similar conditions, on the other hand, continued to grow throughout, although the growth rates assumed sufficiently low proportions between the months of December 1966 and January 1967. As a result of these differences in stem elongation and its ceasation, the two species differ markedly in the length of their growing season. The period of extension growth in *Pterygota* falls short by about 150 days than that of *Manilkara* around the year.

The relative rates of extension growth during different periods are given in fig. 4. The value of

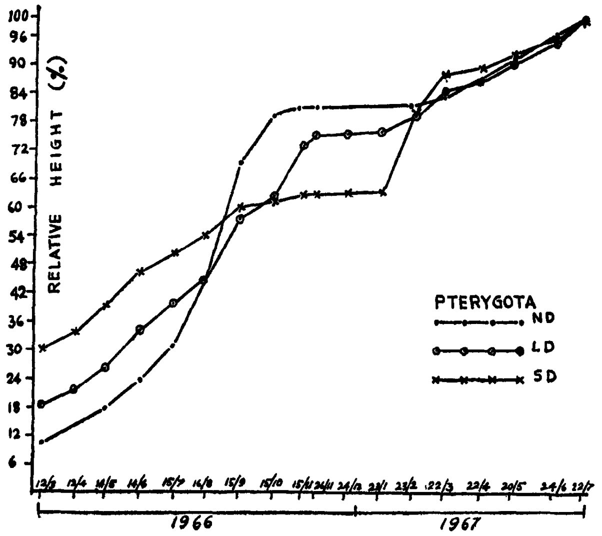

Fig. 2. Relative increase in height at different times as percent of maximum growth taken as 100 of *Manilkara* plants under ND, LD and SD.

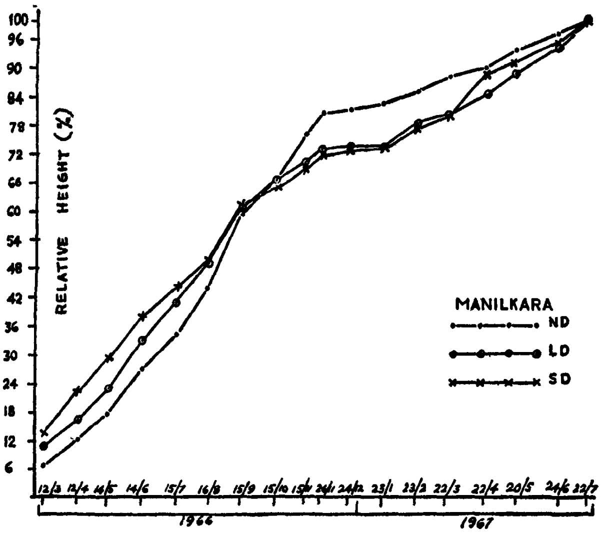

Fig. 3. Relative increase in height at different times as percent of maximum growth taken as 100 of *Pterygota* plants under ND, LD and SD.

rate of extension growth lesser than 0.0002 (arrow mark) may be treated as negligible growth since this indicates a difference of 3 mm or less between the two consecutive visual observations and may be considered to fall within the limits of experimental error. It would be seen that under normal day length conditions, the pattern of growth distribution also differs considerably. In *Pterygota*, the peak of growth period, occurs only once during the end of August, to the end of September, 1966 when a major part of the seasons' total growth appeared to have been completed. Subsequently, the growth rates decline rapidly so much so that it ceases entirely on 26.11.1966. On resumption of growth after dormancy, there is a slow increase in the rates of extension growth. In *Manilkara*, on the other hand, the peak of growth appeared to

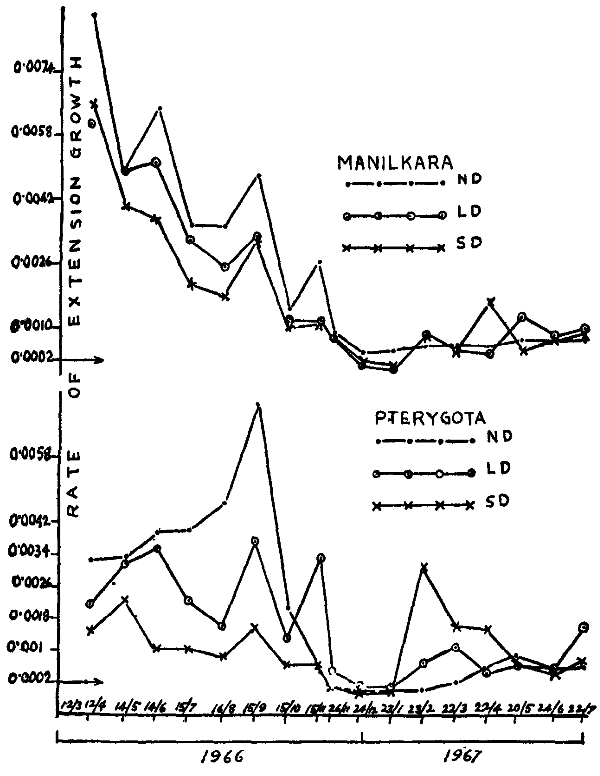

Fig. 4. Rate of extension growth at different time intervals during the experiment in *Manilkara* and *Pterygota* plants under ND, LD and SD.

occur more than once *i.e.* during May-June, August-September, and again in November 1966 with declining rates each time respectively. The growth rates in these species therefore, remained by and large well distributed throughout the growing season. It may thus be concluded that the two species *Pterygota alata* and *Manilkara bojeri* differ between themselves in respect of (*a*) duration of growth period and (*b*) the pattern and rate of growth distribution during the growing season.

(*ii*) *Effect of LD and SD :* The effects of photoperiods on stem elongation are also presented similarly in figs. 1-4. As stated earlier, shorter and longer days than the normal, had markedly influenced the growth in these two species. The overall cumulative growth remained inferior under the influence of these photoperiods. The depression in growth was of comparatively greater magnitude under SD than under LD (Fig. 1). A comparison with the growth curve for the normal days can be made more conveniently in figs. 2 & 3 where the growth curves of fig. 1 are redrawn, the growth at each occasion representing percent increase in stem length over that of maximum growth attained at the end of the experiment considered as 100 in every case. It would be seen that the pattern of extension growth as well as that of distribution have suffered much change.

In *Pterygota,* where the dormant period was quite prolonged under ND, the plants under LD treatment appeared to have assumed dormant condition about one month later (*i.e.* end of December 1966) and resumed growth about two months earlier (*i.e.* the end of January 1967). The peak period of the rate of extension growth (Fig. 4) did not remain restricted around September 1966 as under ND but it remained well distributed through the growing season. There appeared three peaks of extension growth *i.e.* around the month of June, September and again in November 1966. It may be concluded therefore, that LD treatments had a marked effect on *Pterygota* plants where (a) the dormant period of growth was cut short at both ends and (b) the growth distribution became more uniform during the growth period.

Pterygota plants kept under short days, however, appear to have assumed dormant stage at about the same time as ND plants (*i.e.* towards the middle of November 1966) but they resumed growth about two months earlier (*i.e.* towards the end of January 1967). Further, immediately, after resumption of growth there appeared a fairly large increase in their rates of extension growth (Fig. 4). The distribution of extension growth before the onset of dormancy also appear to have remained fairly uniform as the curve is in the form of more or less a flat plateau with two small peaks around March and September 1966. It may be concluded therefore, that *Pterygota* plants when treated with short days, (a) stop growing along with ND plants but resumed growth along with LD treated plants (*i.e.* about two months earlier than ND treatment) and (b) whereas the rate of growth distribution remained fairly uniform throughout the growth period, it assumed a fairly high proportion immediately after the completion of the dormant stage.

Similarly, LD and SD treated plants of *Manilkara* showed a definite suspension of their extension growth at the same time in the beginning of December 1966. Subsequently resumption of growth also appeared at the same time at the end of January 1967 (Figs. 3 & 4). It thus appears that *Manilkara* plants when kept in longer or shorter photoperiod than the normal, undergo a suspended period of growth for about two months. It may be pointed out however, that under normal day conditions too, the growth rates remain fairly small during the same period. Actual increase in stem length in cm under these conditions were as under:

	ND	LD	SD
26.11.1966 to 24.12.1966	0.60	0.10	0.15
24.12.1966 to 23.1.1967	1.00	0.10	0.15
23.1.1967 to 23.2.1967	1.90	1.60	1.20

The values for the months of December 1966 and January 1967 under LD and SD treatments are almost negligible as against apparently positive increase in stem length under ND treatment.

The distribution pattern of the rate of extension growth (Fig. 4) under LD and SD conditions appear to follow more or less similar trends as that of ND plants except for the absence of peak growth in November 1966. It would appear that the growth rates assumed somewhat declining trend about a month earlier under LD & SD than ND plants and this trend accentuated further to almost negligible rates during the months of December 1966 and January 1967. Subsequently to this period too, the growth rates under LD and SD remained more or less similar except that SD plants developed a peak of growth in March and those of LD had it, a month later *i.e.* in April 1967 as against ND plants which had consistently a uniform growth rate. It may, therefore, be concluded that *Manilkara* plants behaved almost in a similar fashion in regard to their extension growth when kept either under LD or SD conditions. About two months of suspended period of growth under these conditions which is virtually absent under ND conditions, probably as a result of reduced rates of extension growth towards the end of their growth period, is a conspicuous feature.

DISCUSSION

The present investigation brings out the following conclusions:

(1) The two species, *Pterygota alata* and *Manilkara bojeri* were quite different both in respect of rate and duration of shoot growth.

(2) The overall cumulative growth in height remained much superior under normal day conditions in both these species. It remained inferior however, under LD and SD conditions.

(3) Long days in *Pterygota* had cut short the period of dormant growth both by delaying its inception as well as by breaking it earlier than normal days.

(4) Short days in *Pterygota* had also cut short the period of dormant growth by only breaking it earlier than normal days. The resumption of growth occurs along with LD conditions.

(5) The rate of extension growth remained more uniformly distributed throughout the growing season under both LD and SD than under ND treatment where a major part of season's growth took place between August-September.

(6) Both LD and SD treatments induced *Manilkara* plants to dormant condition which appeared to have been virtually absent under ND conditions.

(7) *Manilkara* plants had a well distributed, progressively declining growth rates upto December; LD and SD conditions had almost similar pattern of growth distribution except that the declining trend in growth rates were set in about a month earlier than ND.

Each plant species has a characteristic annual cycle of vegetative growth which they exhibit year after year. This may in part be determined by prevailing environmental conditions during the growth period but much of it is under the influence of hereditary differences (Kleb's concept, 1913-18). Even under well controlled similar conditions, Kramar (1958b) found that growing season of red oak was only a few weeks, while that of loblolly pine was over 30 weeks. Similar are the results of various other workers, working with different tree species. Those which continue to grow (a) till September or October, (b) July-August and (c) May or June, formed the three main groups of Waring's (1948) classification. The two species studied may thus be considered to belong to 1st group of this classification as both of them continued to grow upto November (*Pterygota*) or beyond (*Manilkara*). However, the later species show somewhat different behaviour in as much as it grows continuously and is interrupted only with a slow pace of growth rate for about a month or so during December-January.

How is it that the cumulative stem growth under long days remained inferior to that of normal days? And in this respect both the species behave similarly. Evidently it is a long day effect. The light intensity of about 200 ft candles was provided from day light flourescent tubes and incandescent lamps in the present experiment, so that the light treatment contained both red as well as blue part of the spectrum. Most of the workers have used incandescent light for such a study. Kramar (1936) used intensities of 200 ft candles whereas Downs & Borthwick (1966) and Nanda (1963) used 30 ft candle light obtained from tungsten lamps. It is possible therefore, that in the present case a preponderance of blue light has resulted in retarded growth extension. Went and Thimann (1937) observed that larger wavelengths favour the production of auxin precursor, thus enabling plants to grow tall when kept in red light. Subsequently, however, Went (1941) pointed out that the same wavelengths are also most effective in auxin destruction. Went (1941) concluded that growth in stem length depended on the sum total of the light intensities, length and frequency of illumination, colour of light, relative concentration of auxin and auxin precursor. It would thus be seen that the effects of light on extension growth of stem are quite complicated. The pattern of annual cycle of growth as affected by LD and SD conditions may thus be conveniently discussed on the basis of percent of growth occurred during any interval of time (Figs. 2 & 3).

The effect of LD on the cessation and subsequent resumption of growth in *Pterygota* appear to be similar to those of *Michelia champaca, Kydia calycina* and *Salmalia malabarica* described by Nanda (1963) and many other plants of temperate region (*Nitsch* 1957). The onset of dormant condition is delayed by about one month period than under normal days. The resumption of growth also takes place about two months earlier than the normal conditions. However, short days induce the plants to dormant conditions at the same time as ND plants and subsequently the growth is resumed at the same time as LD treated plants. It can not be concluded therefore, that short days in any way change the onset of dormancy. On the other hand, SD treatment shorten the rest period by breaking dormancy much earlier than ND conditions. It would thus appear that in this particular case, the onset of dormancy is not very much under the control of day length conditions. Other physiological factors are also quite important in regulating this mechanism. The results indicate that a different photoperiod other than ND either in the form of SD or LD treatment, hasten the resumption of growth. This again indicates a minor role if any of the photoperiod in breaking dormancy at least in this particular tree species.

Again, in *Manilkara*, the plants assumed dormant period of growth as a result of either SD or LD treatment though only for a short interval of just one month period which corresponded with fairly low growth rates during exactly the same period under ND conditions. The effect may be treated as accentuation of general lower growth status under these conditions. If lower growth rates during the same period under ND conditions are treated as a period of rest, it may be concluded that the plants attain the same condition during the same period under both SD and LD treatments. In other words therefore, *Manilkara* plants remain uneffected by these treatments.

As against general conclusions that long days usually increase the duration of shoot growth while short days decrease it and promote bud formation (*Kramar* 1960), these two species appear to be exceptions. Not much is known about the changes induced by the light conditions in the diurnal cycle of growth of the tropical trees. In their natural habitat, they are not subjected to wide variations in day length around the year. Nanda (1963) studied three tropical tree species and found all of them following more or less the same pattern of growth as stated in the general conclusion above. In view of entirely different behaviour of the two species listed here, it appears that there are many tropical trees which are indifferent to photoperiod treatment and that the cycle of their annual growth is more under the changing influence of total sum of weather conditions rather than entirely on day length conditions.

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