

DIURNAL PERIODICITY IN SOME COMMON FLOWERS

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SUMMARY

The time of flower opening and closure has been observed in twenty species belonging to nine different families. Increasing light initiates opening in some flowers and different species have different thresholds of response. Other species appear to be unaffected by light intensity.

Experiments on the effect of photoperiod on petal movement in *Talinum triangulare* and *Mirabilis jalapa* indicate that the photo-fraction affects the period of the rhythm by altering phase-timing. A close correlation is suggested between phase-timing and the automatic self-pollination mechanism in *Talinum*, possibly also in *Mirabilis*.

Temperature also modifies the period of the rhythm in *Tradescantia* and *Talinum*; in the latter, a temperature of 24°C promoted closing.

INTRODUCTION

Petal and leaf movements have often been studied as expressions of diurnal rhythms in plants; a well-known example is *Kalsanchoë blossfeldiana*, a temperate species (Bunsow, 1953; Bünning and Zimmer, 1962). The present study was undertaken to investigate (1) the timing of petal movement in nature with particular reference to intra-family and intra-generic variability, and (2) the influence of light and temperature on certain aspects of the rhythm. Twenty species belonging to nine families were chosen, but investigations into the influence of photoperiod and temperature were limited to only three species, mainly because most of the species were twiners, climbers or spreading herbs and as such were not easy to transplant into pots for laboratory observation.

METHODS

Field observations

A preliminary survey was made in and around Cape Coast, particularly on the University campus, in early November 1972. Site selection was based on the abundance and copious flowering of a particular species or group of species; areas with few isolated plants or where flowering was limited to a few plants were excluded. Where more than one species of a particular genus appeared together, sites were chosen which showed different species as dominant.

Preliminary observations were made towards the end of November 1972 on the approximate times of flower opening and closing; more accurate observations were made during December 1972 and February 1973, together with light intensities.

Laboratory experiments

These were designed to show the effect of temperature and photoperiod on phase-setting and phase-timing of petal movement in three common flowers—*Talinum*, *Tradescantia* and *Mirabilis*.

(a) *Temperature*. Potted plants of *Talinum* and *Tradescantia* were placed in two treatment rooms with temperatures of 24°C and 29.5°C respectively. Flowers were observed hourly each day and in the case of *Talinum*, counts were made of those that had opened by 10.00 hours for 10 consecutive days in each treatment.

(b) *Photoperiod*. The following treatments were given to potted plants of *Talinum*. (1) 12-hour artificial light between 18.00 and 06.00 hours alternating with 12-h dark (06.00 to 18.00 hours). (2) Continuous light—12 h of natural light supplemented by artificial light during the night. (3) Continuous darkness. (4) Dark interruption of continuous light. An 8-h dark period was given from 14.00 to 22.00 hours. (5) Light interruptions of continuous dark for 8-h and 10-h periods.

In all cases the artificial light was provided by a combination of two white fluorescent tubes and one 40-W incandescent bulb.

Mirabilis jalapa represented a special case in that when a particular flower opened it never open again and, since the flowers are nocturnal, the only treatment that could be given was artificial light during the night. Two different light intensities were used—6000 and 1200 ft-C.

Table 1. Flower opening and closing times for different species. Corresponding light intensities on clear days in 1000 ft.c. (approx)

Family	Species	Opening time (hours)	Closing time (hours)	Opening light intensity		Closing light intensity	
				December	February	December	February
Convolvulaceae	<i>Hewittia sublobata</i>	07.00	13.00	3.0	3.6	14.0	15.8
	<i>Merremia tridentata</i>	07.00	13.00	3.0	3.6	14.0	15.8
	<i>Operculina macrocarpa</i>	08.00	18.00	5.8	6.4	0.6	1.2
	<i>Ipomoea cairica</i>	07.00	14.00	3.0	3.6	12.0	14.9
	<i>I. involucrata</i>	07.00	13.00	3.0	3.6	14.0	15.8
	<i>I. obscura</i>	06.00	13.00	3.0	3.6	14.0	15.8
Malvaceae	<i>Abuliton mauritianum</i>	08.00	18.00	5.8	6.4	0.6	1.2
	<i>Sida cordifolia</i>	09.00	13.00	10.3	11.2	14.0	15.8
	<i>S. stipulata</i>	09.00	15.00	10.3	11.2	10.8	13.3
	<i>Urena lobata</i>	07.00	13.00	3.0	3.6	14.0	15.8
	<i>Wissadula amplissima</i>	08.00	14.00	5.8	6.4	12.0	14.9
Portulacaceae	<i>Portulaca oleracea</i>	10.00	14.00	12.0	13.2	12.0	14.9
	<i>P. quadrifida</i>	11.00	17.00	13.6	14.5	3.0	4.5
	<i>Talinum triangulare</i>	10.00	15.00	12.2	13.2	10.8	13.3
Ficoidaceae	<i>Trianthema portulacastrum</i>	08.00	14.00	5.8	6.4	12.0	14.9
Nyctaginaceae	<i>Mirabilis jalapa</i>	16.00	07.00	8.0	9.1	3.0	3.6
Passifloraceae	<i>Passiflora foetida</i>	06.00	12.00	3.0	3.6	14.8	15.8
Zygophyllaceae	<i>Kallstroemia pubescens</i>	08.00	13.00	5.8	6.4	14.0	15.8
Cucurbitaceae	<i>Luffa cylindrica</i>	06.00	15.00	3.0	3.6	10.8	13.3
Commelinaceae	<i>Tradescantia</i> spp.	05.00	12.00	-	-	14.8	15.8

RESULTS

Field observations

Time of flower opening varied widely from 05.00 hours in *Tradescantia* to 16.00 hours in *Mirabilis jalapa*, but not so much for species belonging to the same family and even less so within the same genus, e.g. *Ipomoea*, *Sida* and *Portulaca* (Table 1). The time of closing, however, varied widely even between species of the same family, e.g. Malvaceae (Table 1). On the other hand, with the exception of *Operculina macrocarpa*, times of closing were similar in

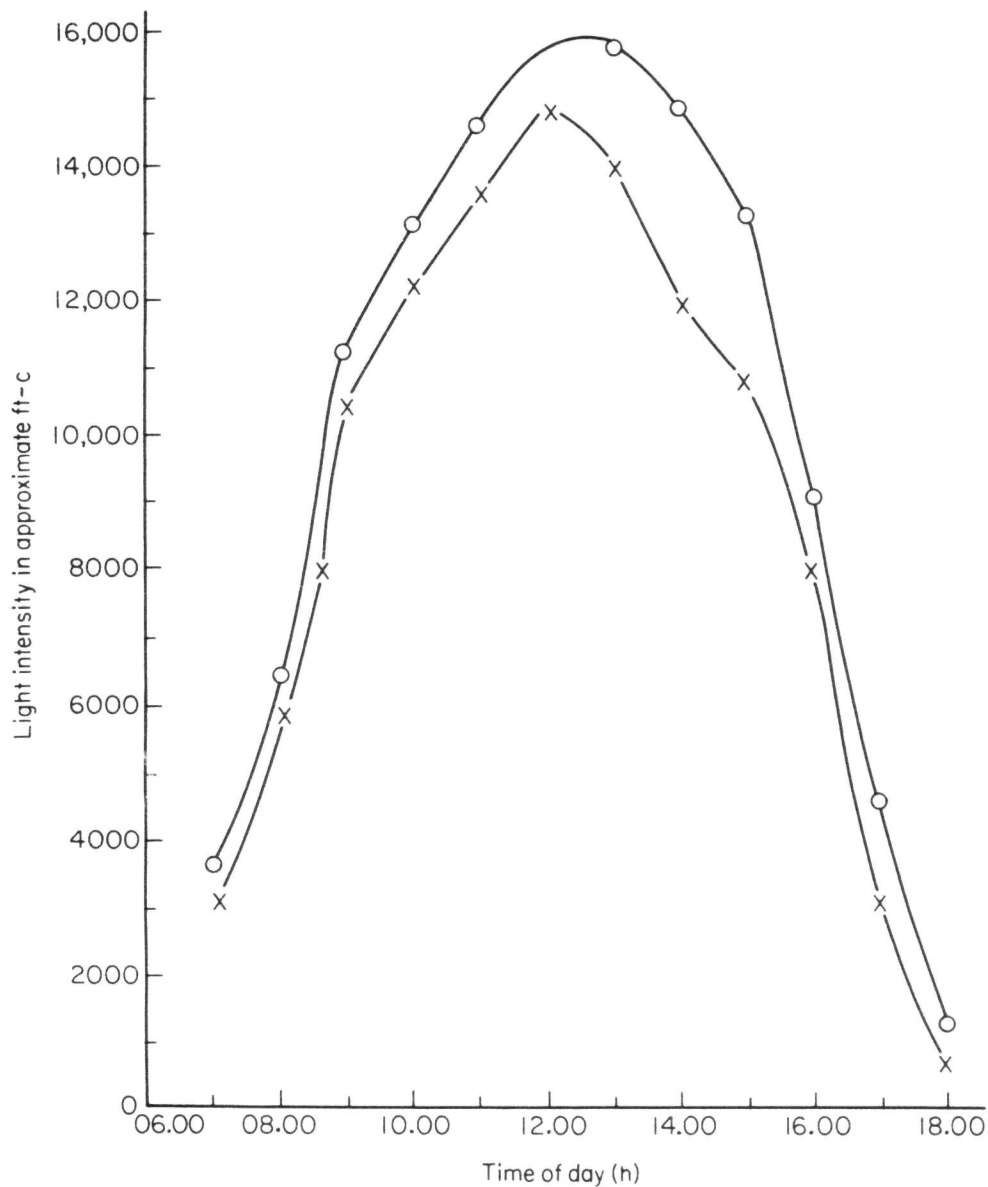


Fig. 1. Average daily variations in light intensity for December 1972 (X) and February 1973 (O) on the University campus (lat. 5° N).

Convolvulaceae species. In other words, the period of the rhythm is more or less the same in species belonging to the Convolvulaceae (Fig. 2) but varies considerably in the Malvaceae (Fig. 4). In the Portulacaceae (Fig. 3), although the periods vary between species, the range is relatively small.

Average light intensities in December and February did not vary much, though were generally higher in the latter (Fig. 1). In both months the highest intensities were recorded between 11.00 and 14.00 hours. For most species closing began around 11.00 hours and was completed by 14.00 hours. This suggests that light intensity acts as a trigger factor.

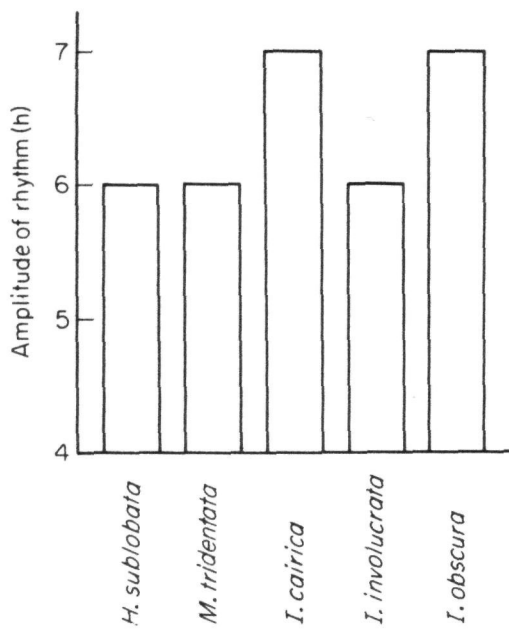


Fig. 2. Periods of rhythm in Convolvulaceae.

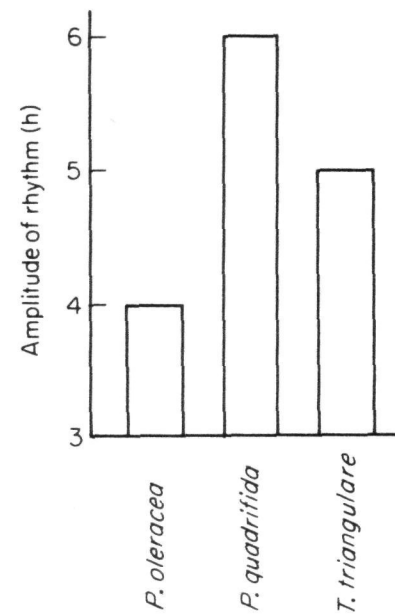


Fig. 3. Periods of rhythm in Portulacaceae.

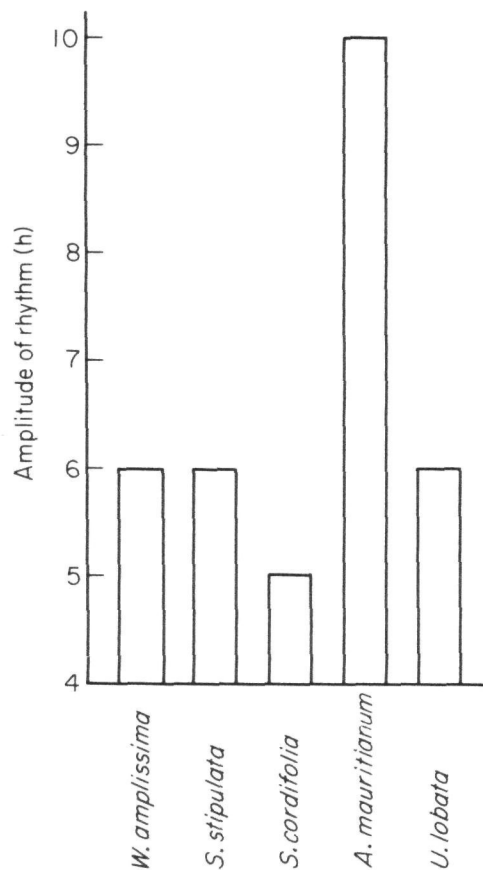


Fig. 4. Periods of rhythm in Malvaceae.

Laboratory experiments

Temperature. In *Tradescantia* the time of onset of flower opening at 24°C and 29.5°C was the same as that observed in the field, i.e. around 05.00 hours. At both temperatures, however, closing was delayed until about 13.00 hours.

Statistical analysis of the data in Table 2 shows that in *Talinum* there is a significant difference ($P < 0.001$) between the number of flowers that opened at 24°C and at 29.5°C; closing at 24°C was delayed by 1 to 2 h.

Table 2. Effect of temperature on the opening of flowers of *Talinum triangulare*

Day	Number of open flowers	
	24°C	29.5°C
1	9	19
2	9	18
3	8	18
4	7	17
5	8	15
6	6	16
7	6	14
8	5	13
9	4	12
10	4	10

Photoperiod. Flowers of *Talinum* from the different sites did not respond to continuous light. It is known that some plants do not open their flowers when exposed to continuous light for an extended period (Arnold, 1959, with *Oenothera*; Todt, 1962, with *Cichorium*). Other workers, however, have found that the rhythm could be restored by 4- to 12-h dark breaks during the light period (Wassermann, 1959; Isaac and Abraham, 1959; Ruddat, 1960).

In continuous darkness closing occurred after the first day of treatment. With 8- and 10-h light breaks during the dark treatment the rhythm could not be restored. The flowers did not respond to the inverse light-dark treatment.

With *Mirabilis*, artificial light given during the night resulted in early closure of the flowers. At a light intensity of about 6000 ft.c. the flowers closed around 03.00 hours and at about 1200 ft.c., around 05.30 hours, instead of 07.00 hours under natural conditions.

DISCUSSION AND CONCLUSIONS

It is clear that the phases of the circadian rhythm are determined by external factors. The fact that most of the species are day-active with regard to petal movement, suggests that light is the most important of these environmental variables.

Light as a phasing-factor

Both light intensity and photoperiod have been shown to affect flower opening and closure. In the present work, four light intensity phasing factors may be recognized. (1) The gradual increase in light intensity in the early morning, which initiates opening, e.g. as in *Ipomoea obscura*. (2) The high light intensity in the late morning or early afternoon, which perhaps raises it above some threshold value and thus determines fade-out of the rhythm, e.g. as in *Passiflora foetida*. (3) The decrease in light intensity during late afternoon or at sunset, which perhaps lowers it below some threshold value and thus initiates closing of the petals, e.g. *P. quadrifida*. (4) Increase in intensity of artificial light during the active night period shortens the period of the rhythm in *Mirabilis jalapa*, i.e. the greater the intensity the earlier the closure.

In some species phase-setting does not seem to be affected by light intensity. It is probable that phase-setting is then mainly controlled by light duration, i.e. the photoperiod, as shown in *Talinum*.

The photoperiodic experiments with *Talinum* show that the ratio of light to darkness (photo-fraction) in a 24-h cycle has a marked influence on phase-setting. When the photo-fraction is close to that of the natural habitat (i.e. 12 h), the flowers open around 10.00 hours and close around 14.00 hours. However, if a cycle of 16 h light:8 h darkness is given, the flowers open during the period corresponding to night under natural conditions. In this particular case, the 8-h dark period was given from 14.00 hours to 22.00 hours and the flowers opened around 02.00 hours and closed around 18.00 hours. The timing of the phases in this experiment is significant.

Previous work on *Talinum triangulare* has suggested that there is an automatic self-pollination mechanism which operates around 14.00 hours and soon after this the flowers close under natural conditions (Laing and Stephens, 1970). Under experimental conditions, the period of the rhythm did not change, indicating that the rhythm is closely associated with the pollination mechanism. The same has been reported by Iwanami and Hoshino (1963) in *Portulaca grandiflora*.

The automatic self-pollination mechanism probably operates in *Mirabilis* too. Evidence for this lies in the fact that each particular flower opens once and no more, and fruit formation then starts in the withered flower. Holtum (1964) has made a similar observation on *Epiphyllum oxypetalum*, a nocturnal species. In addition, the opening of the flowers in *Mirabilis* is accompanied by the emission of odour. This also suggests a close relationship between pollination and phase-setting of the rhythm.

Temperature as a phasing-factor

Temperature has been found to affect phase-timing in both *Talinum* and *Tradescantia*. In both cases, the effect is on flower closure, which is delayed, not on opening; the result is an increasing period. In *Talinum* the fact that fewer flowers opened at 24°C than at 29.5°C has been attributed to an injurious effect of the lower temperature on the petals. When a flower bud opens and closes it fails to open again the following day; thus, new flower buds open each day.

From the present and previous studies on the phenomenon of biological rhythms, it may be concluded that although the rhythm itself is inherent in the species, the underlying mechanism is triggered by various environmental factors. In order to understand this mechanism fully, the inherent aspect of the rhythm needs first to be clearly understood. In the present study a close correlation has been suggested between the rhythm and pollination mechanisms. Further studies in this field may throw more light on inherent aspects.

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