THE SEQUENCE OF FLOWER-OPENING IN TWO SPECIES OF ZINGIBERACEAE

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ABSTRACT. The phyllotaxis of the inflorescence and the timing of individual flower-opening were studied in two species of Zingiberaceae: *Zingiber spectabile* Griff. and *Scaphochlamys kunstleri* (Bak.) Holtt. In *Zingiber spectabile* the inflorescence shows either a (3+5) or a (5+8) phyllotaxis; inflorescences belonging to one clone have the same phyllotactic pattern; flower opening is acropetal and involves a ring-like open-flower zone moving upward towards the inflorescence apex each day. Phyllotaxis of the *Scaphoclamys kunstleri* inflorescence is (1+2); flower opening is acropetal both with reference to the inflorescence axis and to each cincinnus of the inflorescence.

INTRODUCTION

In the family Zingiberaceae the inflorescence is always terminal. It arises either on the vegetative leafy shoot, or on a separate non-leafy shoot. The bracts borne directly on the inflorescence axis, called primary bracts, are spirally arranged, and each bract bears in its axil either a single flower or a monochasial cyme of several flowers (Holttum 1950, 1974). In all species of *Zingiber*, except *Z. clarkei* King, each primary bract subtends one flower. All known species of *Scaphochlamys* have several flowers to a primary bract, except *S. biloba* (Ridley) Holtt. in which there is only one flower to a primary bract. The flowers of Zingiberaceae are purported to last less than twenty-four hours. There has been no study on the sequence of individual flower development in the relatively large *Zingiber* inflorescence, nor on the synchronization in flowering of the monochasial cymes present in the *Scaphochlamys* inflorescence.

MATERIALS AND METHODS

Six inflorescences of *Zingiber spectabile*, belonging to four clones, and one inflorescence of *Scaphochlamys kunstleri* were studied. Each primary bract of an inflorescence was tagged with a number. With the onset of flowering, observations were made daily to record how many flowers had opened in each inflorescence. The position of a flower in an inflorescence is indicated by its subtending bract. All the plants used in this study were in cultivation in the Penang Waterfall Garden, Penang, Malaysia, and I am indebted to the Director, Mr Cheang Koy Choy for permission to use this material.

OBSERVATIONS AND RESULTS

Zingiber spectabile Griff. This has a very handsome inflorescence which varies from 10 to 30 cm in length and 6 to 10 cm in width (Fig. 1a). The inflorescence is terminal on an upright non-leafy flowering stem measuring from 30 to 50

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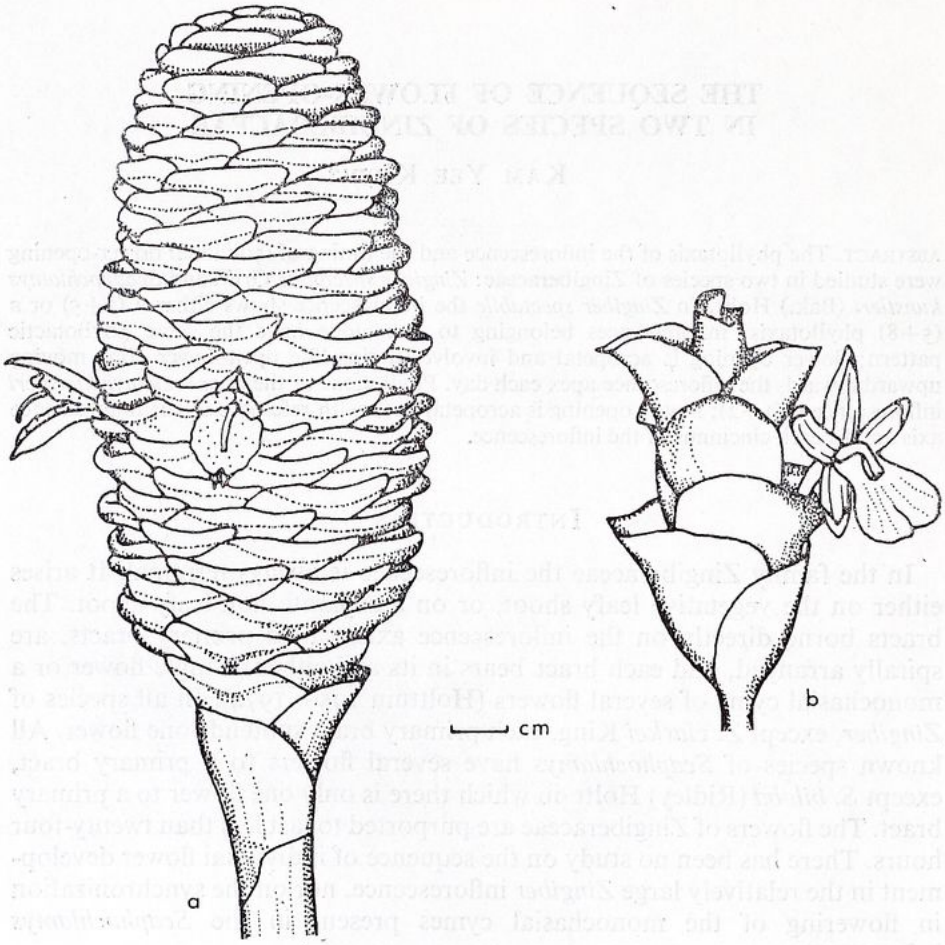

FIG. 1. a, inflorescence of *Zingiber spectabile*; b, inflorescence of *Scaphochlamys kunstleri*.

cm in height. Below the inflorescence the flowering stem bears 2-ranked open sheaths which are bladeless. On the inflorescence axis the primary bracts are spirally arranged. The bracts are yellow when young, becoming orange, then turning a rich red when old. Flowers are short-lived, lasting for a day. On sunny days the flowers open at about 10 a.m. (as reported in Holttum, 1950), but on dull days they open around 2 p.m.

Six inflorescences were studied, and these were labelled A, AA, B, C, D and DD. Inflorescences A and AA were from the same clone; likewise D and DD belonged to one clone. When an inflorescence is viewed from the top (or from the bottom), it is possible to observe curved rows of primary bracts extending outward from the centre, winding in opposite directions. These curved rows, or parastichies, are disposed in two sets, one set running clockwise and the other set running counter-clockwise. These two sets of parastichies intersect, and at the point of intersection a primary bract is located; hence they are contact parastichies.

Phyllotaxis of the bracts is expressed here in terms of the contact parastichies by counting the number of contact parastichies in each set. Two

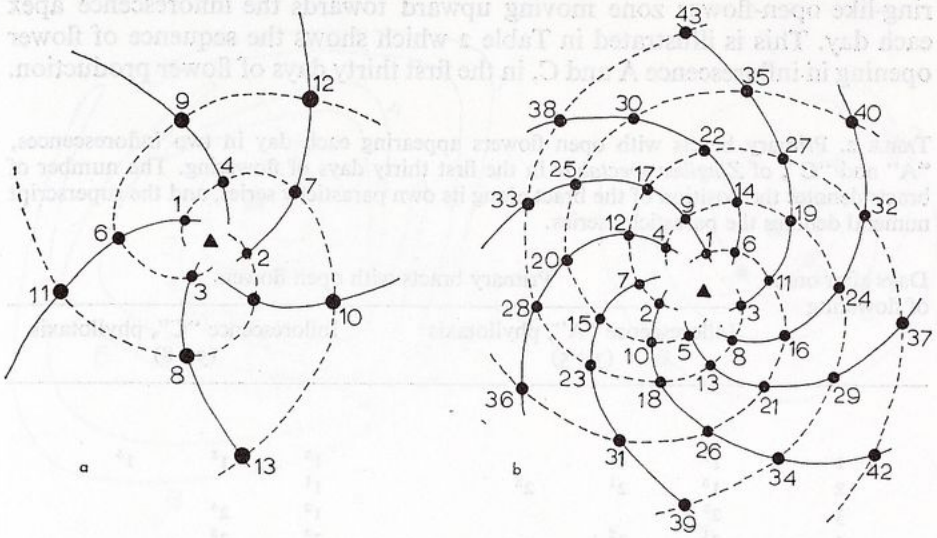

FIG. 2. Phyllotaxis of two inflorescences of *Zingiber spectabile* as seen from the top of the inflorescence. a, inflorescence "A"; extending outward from the centre, there are three contact parastichies in the clockwise direction (broken lines) and five in the counter-clockwise direction (continuous lines); the phyllotaxis is (3+5); the primary bracts along a contact parastichy are numbered. b, inflorescence "B": there are five clockwise contact parastichies and eight counter-clockwise parastichies; thus the phyllotaxis is (5+8).

phyllotactic patterns were found, (3+5) and (5+8), (fig. 2). Inflorescences of the same clone possess the same phyllotactic pattern. The total number of flowers in an inflorescence was found to vary from 95 to 174, and flowering occurred over 39 to 55 days. Table 1 presents data on the phyllotaxis of primary bracts, the number of flowers, and the duration of flowering in the six inflorescences studied.

TABLE 1. Phyllotaxis of primary bracts, total number of flowers, and duration of flowering in six inflorescences of *Zingiber spectabile*.

Inflorescence	Phyllotaxis of primary bracts	Total number of flowers	Duration of flowering (in days)
A	(3+5)	135	50
AA	(3+5)	137	53
B	(5+8)	128	55
C	(5+8)	121	52
D	(3+5)	95	39
DD	(3+5)	174	55

The sequence of flower opening is acropetal. In each clockwise contact parastichy the bracts connected in series along the line of parastichy were numbered in arithmetic progression, with the number '1' for the lowest bract. An inflorescence with contact parastichies (3+5) would then have three clockwise contact parastichy series, beginning with the numbers 1^1, 1^2, and 1^3 respectively. It was found that usually three flowers opened in an inflorescence on any one day and that the positions of these three flowers along their respective parastichy series were almost identical. There appeared to be a

ring-like open-flower zone moving upward towards the inflorescence apex each day. This is illustrated in Table 2 which shows the sequence of flower opening in inflorescence A and C, in the first thirty days of flower production.

TABLE 2. Primary bracts with open flowers appearing each day in two inflorescences, "A" and "C", of *Zingiber spectabile* in the first thirty days of flowering. The number of bracts denotes the position of the bract along its own parastichy series, and the superscript numeral denotes the parastichy series.

Days after onset of flowering	Primary bracts with open flowers							
	Inflorescence "A", phyllotaxis (3+5)				Inflorescence "C", phyllotaxis (5+8)			
1	1^1	1^2			1^3	1^4	1^5	
2	1^3	2^1	2^2		1^1			
3	2^3				1^2	2^4		
4	3^1	3^2			2^3	2^5		
5	3^3	4^1			2^1	3^3	3^4	
6	4^2	4^3			2^2	3^5		
7	5^1	5^2	5^3		3^1	3^3	4^4	
8	6^1	6^2	6^3		3^2	4^5		
9	7^1	7^2			4^1	4^2	4^3	5^4
10	7^3	8^1			5^3	5^5		
11	8^2	8^3	9^1		5^1	5^2	6^4	
12	9^2	9^3	10^1	10^2	6^3	6^5		
13	10^3	11^1	11^2		6^1	7^4		
14	11^3	12^1	12^2		6^2	7^3	7^5	
15	12^3	13^1	13^2		7^1	7^2		
16	13^3	14^1	14^2	14^3	8^1	8^3	8^5	
17	15^1	15^2	15^3		8^2	8^4	9^4	
18	16^1	16^2	16^3		9^1	9^3	9^5	
19	17^1	17^2	17^3		9^2	10^4	10^5	
20	18^1	18^2			10^1	10^3	11^4	
21	18^3	19^1	19^2		10^2	11^5		
22	19^3	20^1	20^2		11^1	11^3	12^4	
23	20^3	21^1	21^2		11^2	12^1	12^3	12^5
24	21^3	22^1	22^2		12^2	13^4		
25	22^3	23^1	23^2		13^3	13^5		
26	23^3	24^1	24^2		13^1	13^2	14^4	
27	24^3	25^1	25^2		14^1	14^3	14^5	
28	25^3	26^1	26^2		14^2	15^4		
29	26^3	27^1			15^1	15^3	15^5	
30	27^2	27^3	28^1		15^2	16^4		

Scaphochlamys kunstleri (Bak.) Holtt. In this species the inflorescence is terminal on the leafy shoot. It varies from 8 to 10 cm long and 4 to 6 cm wide, but is always longer than wide (fig. 1b). The primary bracts of the tagged inflorescence, and of other inflorescences which were examined but not tagged, are arranged in a low spiral, with a (1+2) phyllotaxis (fig. 3a, b). Flowers open in the early hours of the morning and fade by late afternoon. The inflorescence that was studied had eight primary bracts, but in other inflorescences examined the number of primary bracts was found to vary from eight to thirteen.

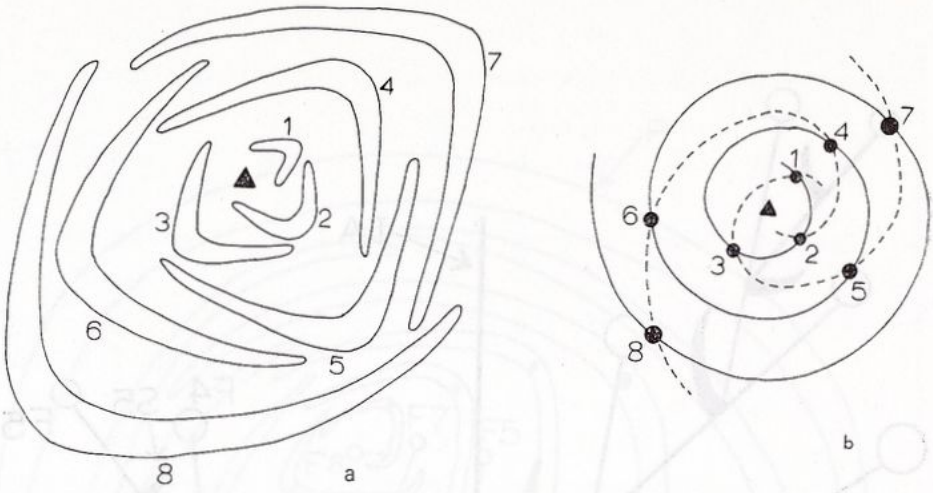

FIG. 3. Phyllotaxis of inflorescence of *Scaphochlamys kunstleri*: a, diagrammatic representation of the arrangement of primary bracts in cross-section—the numbers indicate bract position; b, phyllotaxis of primary bracts with contact parastichies (1+2).

Subtended in the axil of each primary bract is a monochasial cyme with many condensed axes, termed a cincinnus. Each axis of the cincinnus bears a lateral bract and ends in a flower. In agreement with the terminology of Holttum (1974), a bract which is incorporated in an inflorescence but which is not borne directly on the inflorescence axis is called a secondary bract. That is, the lateral bract on each axis of a cincinnus is a secondary bract (fig. 4a). In each cincinnus the secondary bract of the first axis of the cincinnus is largest of all the secondary bracts of that cincinnus and envelops all the other secondary bracts. This secondary bract (LS in figs. 4, 5) is directly opposed to the primary bract which subtends the cincinnus, while successive secondary bracts of the same cincinnus are in an oblique and distichous sequence (fig. 5).

The eight cincinni of the inflorescence studied were tagged as C1 to C8, in acropetal sequence so that C1 was the oldest cincinnus and C8 the youngest. All the cincinni produced ten flowers except for the youngest cincinnus, which produced nine flowers. In each cincinnus the flowers were numbered acropetally as well, starting with F1 for the oldest (basal) flower of the cincinnus (fig. 4). The duration of the flowering period was 75 days, but the actual number of days in which flowers opened was 60. Usually one flower opened on a day, occasionally there would be two open flowers, and on some days no flowers opened.

The sequence of flower opening is acropetal, both with reference to the inflorescence axis and to each individual cincinnus. The oldest flower of the inflorescence, F1 of the first cincinnus, was the first to open. This was followed by F1 of the second cincinnus. The first cycle of flowering was completed with the opening of F1 of the eighth cincinnus. The second cycle of flowering was initiated with the opening of the second oldest flower, F2, of the first cincinnus.

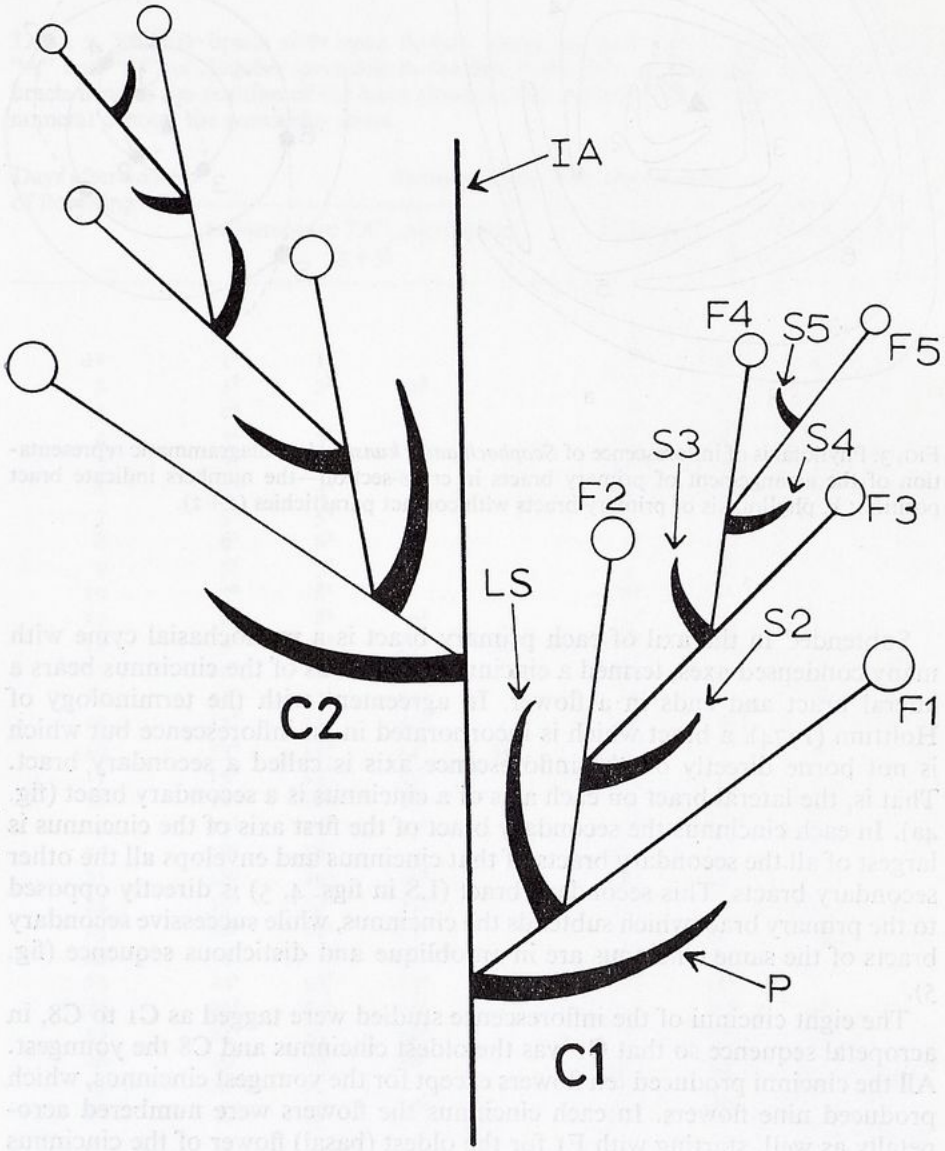

FIG. 4. Diagram to illustrate the branching of the inflorescence of *Scaphochlamys kunstleri*. Only the two lower cincinni are shown. These are C1 and C2, in acropetal sequence. The axes of the cincinni have been extended for convenience. In practice they are very short. Not all flowers have been drawn in. IA, inflorescence axis. Other symbols as in legend for fig. 5.

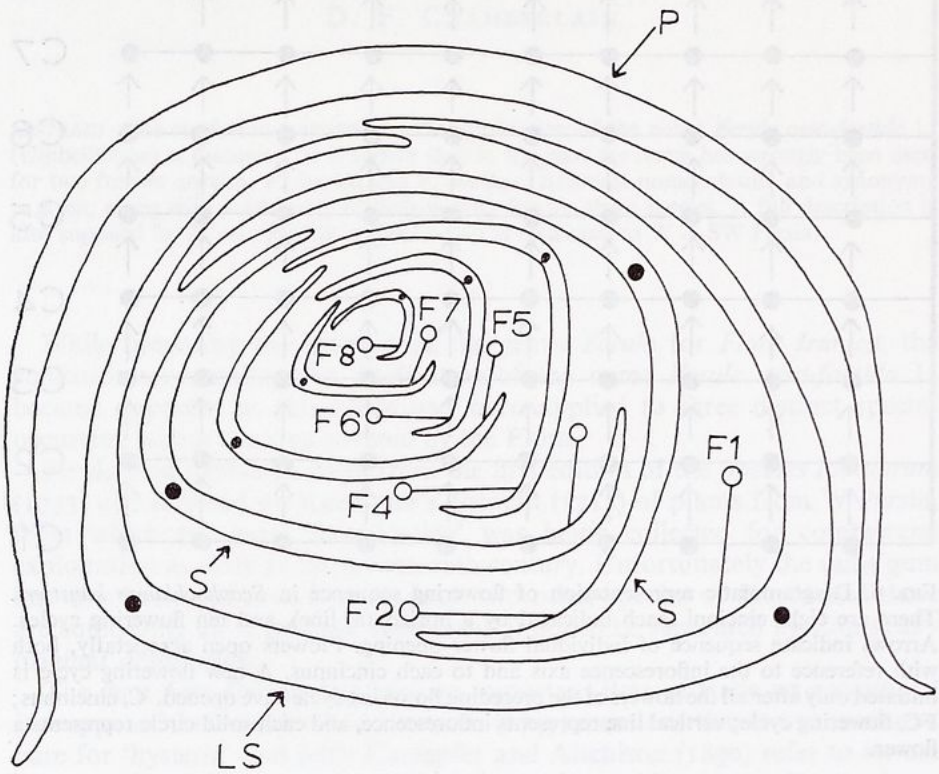

FIG. 5. Cross-sectional representation of one cincinnus of *Scaphochlamys kunstleri*. The lowest secondary bract is directly opposed to the primary bract. F, flower; LS, lowest secondary bract of a cincinnus; P, primary bract; S, secondary bract; a solid circle represents the keel of a secondary bract.

This cycle, as with the first, terminated with the flowering of F2 of the eighth cincinnus. As there were eight cincinni, eight flowers were involved in one flowering cycle. The sequence of flowering in *Scaphochlamys kunstleri* is diagramatically represented in figure 6.

Irregularity in this sequence started to appear with the onset of the fifth flowering cycle. This was mainly due to the flowers of the eighth cincinnus lagging behind the other seven flowers of one cycle. For example, the sixth flower, F6, of the first cincinnus opened before the fifth flower, F5, of the eighth cincinnus had opened. In other words, a new flowering cycle was initiated before the last flower of the preceding cycle had opened.

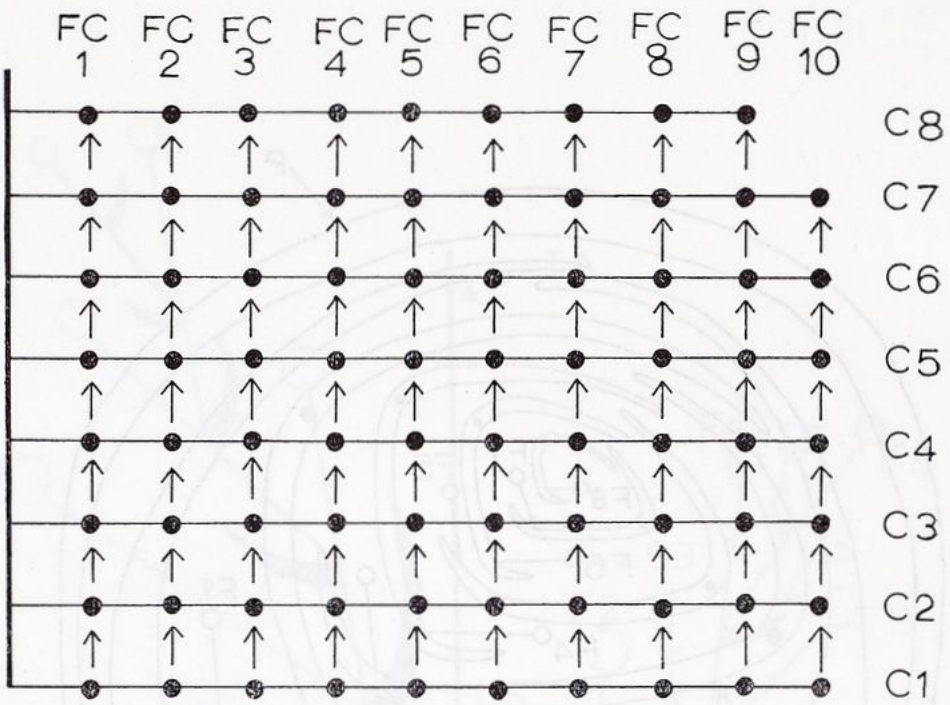

FIG. 6. Diagrammatic representation of flowering sequence in *Scaphochlamys kunstleri*. There are eight cincinni (each indicated by a horizontal line), and ten flowering cycles. Arrows indicate sequence of individual flower opening. Flowers open acropetally, both with reference to the inflorescence axis and to each cincinnus. A new flowering cycle is initiated only after all the flowers of the preceding flowering cycle have opened. C, cincinnus; FC, flowering cycle; vertical line represents inflorescence, and each solid circle represents a flower.

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