A COMPARISON OF FLOWERING BEHAVIOR OF STRELITZIA REGINAE AT FOUR LOCATIONS AS AFFECTED BY AIR TEMPERATURE

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Abstract

Seasonal production of *Strelitzia* flowers in Australia, South Africa, California (USA), and Hawaii (USA) was studied. Air temperatures below 13 C retarded the rate of leaf and flower development, while temperatures above 17 C permitted faster development. We suggest an optimum air temperature range for *Strelitzia* flower production to be between 17 and 27 C as other studies have associated higher temperatures with flower bud abortion.

1. Introduction

Strelitzia is cultivated for local and export markets in many parts of the world because of its unique inflorescences of brilliant orange and blue. Information on flower production has been sparse, and the factors controlling flower production have only recently become the subject of study (Berninger, 1981; Besemer et al., 1982; Criley and Kawabata, 1984; Halevy, 1982; Halevy et al., 1976; Kawabata et al., 1984; van de Venter et al., 1980).

Flower production is seasonal in most areas where *Strelitzia* is grown. In California it blooms from September to May with an October-December peak (Besemer et al. 1982). In its native South Africa, it blooms in the fall-winter-spring period (van de Venter et al., 1980). In Israel, a double peak occurs in March-April and again in September (Halevy et al., 1976). In the low elevations of Hawaii, flowering occurs from June-September (Criley and Kawabata, 1984; Kawabata et al., 1984) and in the fall-winter months at higher elevations.

The purposes of this international experiment were to collect information on the flowering behavior of *Strelitzia* at several locations in order to determine similarities and trends and to relate these to selected weather variables.

2. Material and methods

Participating field sites were located in Queensland, Australia; Port Elizabeth, South Africa; Encinitas, California, USA; and

Waimanalo, Hawaii, USA. A controlled environment experiment was conducted in the phytotron at Hebrew University of Jerusalem in Rehovot, Israel. At each location, selected crowns (fans) and leaves were tagged at regular intervals, usually 2 weeks, and growth of new leaves (leaf emergences, LE), new flower stalks (flower emergence, FE), and flower harvest (flower cut, FC), and new fans were followed for 2 or 3 year periods. The earliest observations were initiated in late 1976 and the most recent (in Australia) were concluded in. Weather variables recorded were: absolute and average minimum and maximum temperatures, rainfall and irrigation, daylength, and solar radiation. Only temperature records based on weekly average values are presented in this report.

Data were summarized using the Statistical Analysis System (Helwig et al., 1979) programs at the University of Hawaii. The following information is presented: leaf emergence intervals (LEI) and seasonality of production, and the timeframes of leaf emergence to flower emergence (LEFE) and flower emergence to flower cut (FEFC).

3. Results

3.1. Effect of temperature on leaf emergence interval (LEI)

Because each leaf normally bears one floral initial in its axil (Fisher, 1976), the frequency of leaf production has a direct relationship to productivity. Results of the Israel phytotron experiment showed quite clearly that warm temperatures caused rapid leaf production (Table 1). The interval between successive leaves was 5.9 weeks for plants grown on a 27/32 C (N/D) regime and 11.3 weeks for plants grown at 12/17 C. Between 22/27 and 17/22, decreasing temperatures lengthened intervals between successive LE.

3.2. Leaf emergence intervals at 4 locations

Previous Hawaii studies reported a LEI range of 48 to 60 days, based on the 3-year monthly average (Criley and Kawabata, 1984). In Australia, the average LEI (considered by month) ranged from 18 to 120 days during 3 years of observations (Table 2). Monthly LEI in California ranged from 38 to 192 days. In South Africa, LEI ranged from 35 to 196 days, although there were periods when no LE activity occurred and the reported average was 9 weeks (van de Venter et al., 1980).

3.3. Seasonality of leaf emergence at 4 locations

The yearly seasonality for LE was most marked in California and South Africa and least in Hawaii (Table 3). No leaves emerged in South Africa during winter while most emerged during the summer. Leaf production also was low in California in winter, where 50% of the leaves were produced during the summer. The pattern was similar for Australia with about 15% of the leaves being produced during the winter but close to 40% during the summer. Leaf production in Hawaii was relatively constant with 20% produced during December-February and the 27% of the yearly total produced during June-August.

3.4. Leaf productivity

Leaf productivity was defined as the percent of leaves emerging in any one month which ultimately bore a flower in the leaf axil. Differences in the methods of data collection limited the number of points for South Africa and California. Of 109 leaves which emerged during 1979 in California, only 31 subsequently produced a flower. During the 5 months November through March, 17 leaves produced only 3 flowers while the best flowering rates were for the 19 leaves/12 flowers produced during April-May. In South Africa where the leaves emerged mainly during the summer, the pattern was biased towards these leaves as there were none emerging in the winter months. Fewer than 50% of the leaves emerging in the period April through August in Hawaii produced flowers, whereas the highest productivity (65-80%) was for leaves produced in the October through February period (Criley and Kawabata, 1984). The method of data collection did not permit an analysis for Australia.

3.5. Seasonality of flower production

Distribution of flower production is shown in Table 4 by the fraction that each month represents of the total yearly harvest. Thus the summer months were high for Hawaii, fall-winter months for South Africa and California, and late winter-spring for Australia.

3.6. Flower development

3.6.1. Leaf emergence to flower emergence

As shown in Table 5, the longest time periods for LEFE at each site were when development occurred through the winter months. Nearly 11 months were required for LEFE in South Africa and California. The shortest LEFE timeframe is about 5 to 5-1/2 months in Australia and Hawaii which also have the warmest conditions for the longest periods of time.

3.6.2. Flower emergence to flower cut

The fastest flower development from the time the stalk was visible was about 8 weeks in both Hawaii and Australia in the summer months (Table 6). The slowest FEFC required about 28 weeks in South Africa through the winter months, whereas in both Australia and California, FEFC took about 16 weeks through the fall-winter months and 9 weeks in spring.

3.6.3. Leaf emergence to flower cut

As previous work has demonstrated (Criley and Kawabata, 1984; Fisher, 1976), the timeframe for flower development spans more than a year from the first identifiable floral initial until the flower reaches anthesis. Data were not available from the different sites for stages of floral development prior to FE, but measurable progress may be assumed to coincide with the emergence of the leaf which subtends the flower (Kawabata et al., 1984).

Table 7 summarizes the extremes of LEFC by month of LE for the 4 sites. The least variation is shown in Hawaii, with less than a year spent in LEFC, while in both South Africa and California, LEFC requires more than a year.

3.7. Temperature conditions during the observation years

Air temperatures showed the least winter to summer variation in Hawaii, less than 10 C between extremes. The range of differences was similar in California but both maxima and minima were well below Hawaii. In Australia, the maxima were similar to Hawaii but the low temperatures were much lower. In South Africa, the native habitat of Strelitzia, long periods of cool temperatures prevailed with only brief periods when the temperatures rose above 20 C.

The temperatures during long and short periods of LEFE and FEFC were examined for the four sites (Table 8). Short development periods generally had minimum temperatures above 13 C while long development periods had minimums under 11 C.

Information derived from tables 5,6 and 8 was used to produce Figure 1. The trend to increased time spent in development at cool temperatures was both obvious and expected. Seven of the development events took place during periods with air temperatures under 11 C, including the longest durations for LEFE and FEFC in Australia, South Africa, and California. Minimum FEFC durations were around 50 days in Hawaii and Australia (Ave. = 55), the sites with the most consistently short development periods, and a regression plot of development time versus air temperature intercepts this minimum at 17 C.

As the Israeli phytotron experiment indicated that under 17 C, leaf production slowed, we examined site temperature records to determine the duration of such cool periods (Table 9). There was good agreement between the periods of long LEFE, FEFC, and LEFC the months of 8 to 11 C minimum temperatures for the 3 sites in more extreme latitudes, but we are unable to suggest an appropriate base temperature at this time.

4. Discussion

We have previously demonstrated that at least a portion of the seasonality of flowering may be due to flower bud abortion (Criley and Kawabata, 1984; Kawabata et al., 1984). Flower buds apparently fail to develop after reaching a certain stage if the temperature is too high, and a critical air temperature of 27 C was proposed as a potential cause. (Kawabata et al., 1984).

Development may be retarded at cool temperatures, but when temperatures warm enough to permit development do resume, a surge of flowering can result. In California and South Africa, in particular, the period of warm temperatures may be too brief for all of the development which must take place. Here, the final phases of flowering may occur during or after another period of low temperature.

In this study, low temperatures were clearly associated with periods of slow development. Thus, the temperature range is critical to uniform flowering in Strelitzia. At this time, we suggest that temperatures ranging between 27 and 17 C would provide optimum environmental conditions for rapid and uniform flowering.

Journal Series No. 3072 of the Hawaii Institute of Tropical Agriculture and Human Resources.

References

Berninger, E. 1981. Travaux sur Strelitzia. Sta. Amel. Pl. Flor., Frejus, Rapt. Act. 1977-1980 :67-76.

Besemer, S. T., R. B. McNairn, and A. H. Halevy. 1982. Bird-of-paradise clonal selections. Part II. Flower production. Flor. Rev. 170(4402):16, 18.

Criley, R. A. and O. Kawabata. 1984. Development of the flower spike of bird of paradise and its flowering period in Hawaii. J. Amer. Soc. Hort. Sci. 109:702-706.

Fisher, J. B. 1976. Development of dichotomous branching axillary buds in Strelitzia (Monocotyledonae). Can. J. Bot. 54:578-592.

Fransen, C. M. 1977. Biedt strelitziateelt nog perspectif? [Does strelitzia productin still have good prospects?] (Dutch) Vakblad v Bloemisterij 32(43):46-47.

Halevy, A. H. 1982. An international experiment on environmental factors affecting flowering of Strelitzia reginae. Abstr. 21st Intern. Hort. Congr. No. 1777.

Halevy, A. H., A. M., Kofranek, and J. Kubota. 1976. Effect of environmental conditions on flowering of Strelitzia reginae Ait. HortScience 11:538.

Helwig, J. T. and K. A. Council. 1979. The SAS User's Guide, 1979 edition. SAS Institute, Raleigh, NC.

Kawabata, O., R. A. Criley, and S. R. Oshiro 1984. Effects of season and environment on flowering of bird of paradise in Hawaii. J. Amer. Soc. Hort. Sci. 109:706-712.

Noordegraaf, C. V. 1975. Teelt van Strelitzia. [Culture of Strelitzias.] (Dutch) Vakblad v Bloemisterij 30(20):12-13.

Noordegraaf, C V. and Th. M. v de Krogt. 1976. Produktie en bloei van Strelitzia. [Productivity and flowering of Strelitzia.] (Dutch) Vakblad v Bloemisterij 31(49):18-19.

van der Krogt, Th. M. 1981. Sortimentsvergetering by strelitziateelt mogelik. [An improvement in the range of material is possible in Strelitzia culture.] Vakblad v Bloemisterij 36(4):44-45.

van de Venter, H. A., J. G. C. Small, and A. H. Halevy. 1980. Some characteristics of leaf and inflorenscence production of Strelitzia reginae Ait. in Port Elizabeth. J. S. Afr. Bot. 46:305-311.

Table 1 - Leaf emergence intervals (LEI) in Israeli phytotron experiment. Duration of 100 weeks.

Night/Day C	No. Leaves	LEI (days) ±SE
27/32	43	41.3 ± 14.7
22/27	42	39.2 ± 14.7
17/22	40	65.1 ± 26.6
12/17	25	79.1 ± 42.7

Table 2 - Leaf emergence intervals (LEI) and average numbers of leaves produced per fan.

Site	Range of LEI (days)	Leaves/fan/yr
Australia	18-120	7.4
South Africa	35-196	4.0
California	38-192	4.5
Hawaii	48- 60	7.7

Table 3 - Seasonality of leaf emergence and percent of yearly total which the time period represents

Site	Low Month(s)	(%)	High Month(s)	(%)
Australia	July	3.0	Nov	12.5
South Africa	June	0	Dec	14.0
California	Dec-Jan	0	Jul	22.0
Hawaii	Jan-Feb	5.5	Oct	11.8

Table 4 - Seasonality of flower production and percent of the total yearly harvest which the time period represents.

Site	Low Months	(%)	High Months	(%)
Australia	Apr-May	18.7	Aug-Oct	41.5
South Africa	Sep-Jan	27.3	Apr-Jul	49.5
California	Jun-Aug	9.7	Oct (high)	16.0
			Nov-May	67.0
Hawaii	Dec-Apr	21.2	Jun-Oct	63.7

Table 5 - Range of leaf emergence to flower emergence (LEFE) by month of leaf emergence (LE).

Site	Base Period (years)	Month(s) of Shortest LEFE	LEFE (Days)	Month(s) of Greatest LEFE	LEFE (days)
Australia	3	Oct-Nov	150	Apr	253
South Africa	2	Sep	154	Feb	309
California	2	Jan-Feb	192	Oct-Nov	312 to 324
Hawaii	3	Apr-May	172	Oct	195
				Jan-Feb	190

Table 6 - Range of flower emergence to flower cut (FEFC) by month of flower emergence (FE).

Site	Base Period (years)	Months of Shortest FEFC	FEFC (days)	Month(s) of Greatest FEFC	FEFC (days)
Australia	3	Dec-Jan	56	Apr	117
South Africa	2	Oct	112	Mar	196
California	2	Apr-May	65	Nov	115
Hawaii	3	Jul-Sep	55	Dec-Jan	75

Table 7 - Range of leaf emergence to flower cut (LEFC) by month of leaf emergence (LE).

Site	Base Period (years)	Month(s) of Shortest LEFC	LEFC (days)	Month(s) of Greatest LEFC	LEFC (days)
Australia	3	Sep-Oct	240	Apr	325
South Africa	2	Sep	266	Feb	504
California	2	May, Jul	313	Oct	502
Hawaii	3	May, Aug	238	Oct	255

Table 8 - Average minimum and maximum temperatures during the observation periods for months which correspond to short and long development periods for LEFE and FEFC.

	Min/Max Temp during period of shortest development		Min/Max Temp during period of longest development	
Site	LEFE	FEFC	LEFE	FEFC
Australia	9/24	15/25	11/22	10/24
South Africa	16/26	16/24.5	8.5/20	10/20
California	13/24	13.5/20	8/17-23	9/19
Hawaii	22/29	22/28.5	18/27	18.5/27

Table 9 - Duration of time periods (days) with maxima above 27 C and minima below 17 C at 4 sites and month in which the time period began.

Site & Year	Days < 17 C	Month	Days > 27 C	Month
Australia				
1978	---	---	134	Nov
1979	203	Apr	150	Nov
1980	150	May	---	Oct
South Africa				
1977	251	Feb	16	Jan
1978	235	Mar	0	---
California				
1977-1978	257	Oct	0	---
1978-1979	225	Oct	11	Sep
1979-1980	257	Oct	16,	Sep
			21	Dec
Hawaii				
1977	0	---	230	Apr
1978	5	Feb	235	Apr
1979	11	Jan	294	Mar

Figure 1. Relationship between days spent in LEFE and FEFC and air temperature for slow and fast development at each site.