Literature Cited

1. Emery, G. C. and H. M. Munger. 1970. Effects of inherited differences in growth habit on fruit size and soluble solids in tomato. J. Amer. Soc. Hort. Sci. 95:410–412.
2. Hale, C. R. and R. J. Weaver. 1962. The effect of developmental stage on direction of translocation of photosynthate in *Vitis vinifera*. Hilgardia 33:89–131.
3. Hewitt, J. D. and M. A. Stevens. Growth analysis of two tomato genotypes differing in total fruit solids content. J. Amer. Soc. Hort. Sci. 106:723–727.
4. Ho, L. C. 1979. Regulation of assimilate translocation between leaves and fruits in the tomato. Ann. Bot. 43:437–448.
5. Khan, A. A. and G. R. Sagar. 1966. Distribution of ^{14}C-labelled products of photosynthesis during the commercial life of the tomato crop. Ann. Bot. 30(120):727–743.
6. Khan, A. A. and G. R. Sagar. 1967. Translocation in tomato: the distribution of the products of photosynthesis of the leaves of a tomato plant during the phase of fruit production. Hort. Res. 7:61–69.
7. Kilburn, D. M. and P. M. Taylor. 1969. Effect of sulfhydryl reagents on glucose determination by the glucose oxidase method. Anal. Biochem. 27:555.
8. Liu, P., D. H. Wallace, and J. L. Ozbun. 1973. Influence of translocation on photosynthetic efficiency of *Phaseolus vulgaris* L. Plant Physiol. 52:412–415.
9. MacRae, J. C. 1971. Quantitative measurement of starch in very small amounts of leaf tissue. Planta 96:101–108.
10. Rick, C. M. 1974. High soluble solids content in large fruited tomato lines derived from a wild green-fruited species. Hilgardia 21:493–510.
11. Tanaka, A., K. Fujita, and M. Shioya. 1974. Nutrio-physiological studies on the tomato plant. II. Translocation of photosynthates. Soil Sci. Plant Nutr. 20:163–171.
12. Walker, A. J. and L. C. Ho. 1977a. Carbon translocation in the tomato: carbon import and fruit growth. Ann. Bot. 41:813–823.
13. Walker, A. J. and L. C. Ho. 1977b. Carbon translocation in the tomato: effects of fruit temperature on carbon metabolism and the rate of translocation. Ann. Bot. 41:825–832.
14. Walker, A. J. and J. H. M. Thornley. 1977. The tomato fruit: import, growth, respiration and carbon metabolism at different fruit sizes and temperatures. Ann. Bot. 41:977–985.
15. Walker, A. J., L. C. Ho, and D. A. Baker. 1978. Carbon translocation in the tomato: pathways of carbon metabolism in the fruit. Ann. Bot. 42:901–909.
16. Wareing, P. F. and J. Patrick. 1975. Source-sink relations and the partition of assimilates in the plant. p. 481–499. In: J. P. Cooper (ed.) Photosynthesis and productivity in different environments. Cambridge Univ. Press, London.
17. Warren-Wilson, J. 1972. Control of crop processes. p. 7–30. In: A. R. Rees, K. E. Cockshull, D. W. Hand, and R. G. Hurd. (eds.) Crop processes in controlled environments. Academic Press, London and New York.

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Relationship of Number of Long Nights to Meristem Development and Flowering in Kalanchoe[1]

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Abstract. **Cultivars of *Kalanchoe blossfeldiana* Poelln. varied in number of long nights required for complete flower initiation and development. 'Montezuma' and 'Texas Sunset' requried 14 long nights, while 'Pixie', 'Nugget', 'Cactus Candy', 'Goddess', 'Tobasco', 'Osage Orange', 'Toltec', 'Adobe Rose' and 'Rotkappchen' required 15 to 28 nights. Height of apical meristems increased in 'Montezuma' after 7 long nights, but changes were not evident in 'Pixie' until 9 long nights. Scanning electron microscopic analysis showed first evidence of sepal primordia in 'Pixie' after 28 long nights—6 nights later than 'Montezuma'. Differences in the number of long nights required for flower induction were related to delayed floral initiation rather than organogenisis or maturation.**

With the development of new cultivars which vary in flower colors and time from floral induction to anthesis, kalanchoes are an important floricultural crop (6). Kalanchoes are short-day plants with the number of long nights required for plants to reach marketable flowering varying with cultivar (2, 7, 8, 14) and temperature (6, 8, 10, 14).

The number of long nights required for flower induction has been related to histochemical changes in meristems (12), hormonal translocation (12), and exogenous growth regulator application (3, 9). Early meristem dimensional changes have been reported to occur 8 to 10 days after photoinduction (5,13). However, the developmental stage necessary for further development and anthesis to occur if plants are shifted to short nights has not been identified.

This study was initiated to relate the effects of longer sequences of long nights to floral induction, initiation, and development in these new cultivars; and via meristematic examination, to determine the earliest induction, initiation, or development stage at which anthesis occurs with the minimum number of long nights.

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Materials and Methods

Cultural. Kalanchoe rooted cuttings were received from commercial propagators and planted in the fall and winter of 1977 and 1978. Plants were potted in 15-cm containers using a mixture of 1 sand:1 peat:1 perlite (by volume) amended with 5.6 kg dolomite, 2.9 kg superphosphate and 1.8 kg Perk/m^3 (a micronutrient blend manufactured by Estech General Chemicals Corp., Chicago, Ill.) Plants were fertilized at every watering with a 25N–OP–20.8K fertilizer source at a rate providing 200 ppm N. Minimum night temperatures of 16°C were maintained.

1977 experiment. 'Adobe Rose', 'Cactus Candy', 'Goddess', 'Montezuma', 'Nugget', 'Osage Orange', 'Pixie', 'Rotkappchen', 'Texas Sunset', 'Tobasco', and 'Toltec' kalanchoes were planted November 17, placed in a lightly shaded glass greenhouse (ca. 80 klx), and illuminated nightly from 2200 to 0200 HR for 2 weeks with a minimum of 6 W m^{-2} from an incandescent light source, after which long night treatments were provided by covering the greenhouse bench with a black, opaque woven cloth from 1700 to 0800 HR. Plants were provided long night conditions for 2 or 4 weeks and returned to short night conditions or given long nights until anthesis. There were 6 plants of each cultivar per experimental unit with 4 replications arranged in a randomized complete block design. Plant height, plant width, and cyme length (distance from the last leaf to the uppermost flower) were measured at experiment termination.

1978 experiment. 'Montezuma' and 'Pixie' rooted cuttings were planted December 15 and grown in a double polyethylene covered greenhouse. Plants were given 7 short nights then transferred to long nights. Four plants were returned to short nights every other day beginning with the 5th long night through 49 long nights. When each 4-plant group was returned to short nights, meristems from 4 companion plants were removed to trace meristem development. A randomized complete block design with 4 replications was used.

Leaf primordia were removed, then excised meristems were fixed in formalin acetic acid (FAA). Height and width of excised meristems were measured and stage of development determined using a binocular light microscope. A numerical scale was established to determine the mean developmental stage, as has been previously done for *Xanthium* (11), with 0 = vegetative, 1 = sepal primordia present, 2 = petal primordia present, 3 = stamen present, and 4 = stigma present.

Fixed meristems remained in FAA for 48 hr, then were dehydrated in a graded ethanol series, 15 min per solution. They were then critical-point dried using clean liquid CO_2. Meristems were mounted on aluminum stubs using Tube Coat adhesive, sputter coated with 550 Å of gold-paladium, and viewed in a JEOL S-450 scanning electron microscope using an accelerating voltage of 20 Kv.

Results and Discussion

Kalanchoe cultivars responded differently to the number of long nights in the 1977 studies with all cultivars forming 3 or more cymes when given 28 long nights (Table 1). 'Texas Sunset' and 'Montezuma' plants flowered as a result of only 14 long nights, while 15 to 28 long nights were required to cause flowering of other cultivars. Carlson (2) and Pertuit (10) previously indicated the number of cymes and percent flowering increased with more long nights. Long nights generally did not affect plant height and cyme length, but this response was cultivar dependent. Plant height was reduced in 'Nugget', 'Toltec', 'Montezuma', and 'Rotkappchen' when more than 28 long nights were

Table 1. Influence of number of long nights on growth and flowering of kalanchoe cultivars.

	Height (cm)[z]			Cyme length (cm)[y]		
	No. long nights			No. long nights		
Cultivar	14	28	Continuous	14	28	Continuous
Adobe Rose	---[w]	24.7a[x]	26.0a	---[w]	13.0a	12.8a
Cactus Candy	---	29.3a	26.8a	---	17.0a	16.3a
Goddess	---	21.2a	20.7a	---	14.0a	12.5a
Montezuma	31.6b	34.3a	29.3b	23.8a	25.5a	21.5b
Nugget	---	23.7a	19.5b	---	14.1a	13.3a
Osage Orange	---	25.5a	23.2a	---	17.8a	14.2b
Pixie	---	30.3a	26.5a	---	19.7a	18.5a
Rotkappchen	---	33.8a	25.7b	---	20.0a	15.2a
Texas Sunset	22.3a	22.7a	22.3a	13.5a	10.3b	13.2a
Tobasco	---	31.3a	28.0a	---	18.7a	16.8a
Toltec	---	35.8a	32.2b	---	25.0a	20.3b

[z]Height measured from pot rim to uppermost floret.
yLength measured from uppermost leaf to terminal floret.
[x]Mean separation within rows by Duncan's multiple range test, 5% level.
[w]Flower development was observed only in 'Montezuma' and 'Texas Sunset' with 14 long nights.

Table 2. Influence of number of long nights on growth and flowering of 'Montezuma' and 'Pixie' kalanchoes.

No. long nights	Meristem height (μm ± SD)	Meristem width (μm ± SD)	Days to first open floret	No. florets
		Montezuma		
0	90. ± 18	47. ± 19	---[y]	---[y]
5	92. ± 34	90. ± 16	---	---
7	115. ± 28	112. ± 19	---	---
9	175. ± 49	77. ± 30	66.0	0.1
11	160. ± 39	95. ± 26	61.8	28.8
13	177. ± 41	127. ± 30	53.7	201.3
15	182. ± 43	155. ± 28	54.9	186.5
17	210. ± 34	195. ± 36	53.6	295.8
19	185. ± 46	170. ± 19	54.7	286.3
21	170. ± 24	157. ± 29	54.6	292.8
23	170. ± 24	157. ± 13	53.1	292.0
25	---[z]	---[z]	54.6	339.0
27	---	---	54.2	325.3
29	---	---	53.7	330.3
31	---	---	54.4	294.3
		Pixie		
0	85. ± 19	60. ± 16	---[y]	---[y]
5	72. ± 22	72. ± 18	---	---
7	95. ± 28	92. ± 18	---	---
9	107. ± 32	60. ± 22	---	---
11	145. ± 38	80. ± 23	---	---
13	135. ± 47	92. ± 29	---	---
15	157. ± 32	112. ± 26	---	---
17	175. ± 37	152. ± 28	68.3	35.0
19	162. ± 23	160. ± 18	67.6	41.3
21	160. ± 27	147. ± 19	69.1	56.0
23	165. ± 38	150. ± 22	66.6	29.3
25	142. ± 27	125. ± 11	66.5	90.8
27	145. ± 29	127. ± 26	63.5	163.8
29	---[z]	---[z]	63.5	152.0
31	---	---	62.9	172.5

[z]Meristem was not measured since floral organs were present.
[y]Flower development did not occur in treatments without values.

applied. Continuous long nights reduced cyme lengths of 'Osage Orange', 'Toltec', and 'Montezuma'.

Flowering responses of 'Montezuma' and 'Pixie' to long night treatments were also observed in 1978 studies, where meristem size and floral development were evaluated at 2-day intervals (Table 2). Morphological expression of flower initiation was evident in both cultivars after 5 long nights in 'Montezuma' and 7 in 'Pixie', as the flat, rectangular-shaped vegetative meristem (Fig. 1A) increased in width. The initial width increase was followed by a temporary reduction which was probably associated with elongation of the primary floret (Fig.1B, Table 2). A similar change in meristem height was observed after 7 long nights in 'Montezuma' or 9 in 'Pixie' with the transition to flowering being more rapid in 'Montezuma' (Fig. 1C). These dimensional changes preceded organ differentiation and were more rapid than previously reported by Stein and Stein (13) and Fredericq (5). They observed increases in height and width of the apex 8 to 10 days after the start of long nights. However, this difference might be expected, since cultivars used in these studies have been developed for earliness of flowering compared to seed-propagated types used in earlier studies. Leaves and bracts were arranged in a decussate phyllotaxy (Fig. 1C).

Floral development was evidenced by the presence of nonfused and pointed sepal primordia (Fig. 1C, 2A). Sepals were visible after 22 days in 'Montezuma' and 28 days in 'Pixie'. Axillary or lateral floret initiation occurred simultaneously with the sepals (Fig. 1C) and represented the earliest development of the dichasial cyme and served as the main axis of the inflorescence. Petal, stamen, and stigma differentiation followed a similar time schedule in both cultivars once sepals were initiated (Fig. 3). Rounded petals were present 2 days after sepals with stamen and stigma differentiated about 5 and 13 days later, respectively. Petal primordia elongated to enclose the 8 stamens and stigma (Fig. 2A-C), and the meristem was nearly square once the gynoecium, with 4 carpels, had differentiated (Fig. 2D).

Schwabe (12) related flower initiation to production of an adaptively formed enzyme in sufficient quantity to promote flowering, or to production of an inhibitor which interferes with enzyme formation under noninductive conditions. Therefore, cultivars reaching anthesis with few long nights may produce an enzyme in greater quantities than cultivars requiring longer inductive cycles, or the enzyme threshold required for the process is lower in such cultivars. The numbers of long nights to cause anthesis in 'Montezuma' and 'Pixie' were 17 and 27, respectively. This timing difference was observed at flowering as 'Pixie' flowered about 10 days later than 'Montezuma'. The enzymatic or hormonal changes leading to flowering must have become irreversible after sepal differentiation in both cultivars, because lateral shoots on plants which were shifted to noninductive conditions prior to sepal initiation did not reach anthesis. These chemical changes appear to be temperature-dependent, since Turner (14) has shown 'Goddess', 'Rhumba', 'Rotkappchen', and 'Tobasco' to be unaffected by night temperatures of 25 to 30°C while 'Toltec' and 'Montezuma' showed incomplete flowering at these temperatures. Thus, enzymatic or hormonal changes following sepal differentiation must be involved in organogenesis and maturation rather than complete flowering of the cyme.

Differences in the number of long nights required by kalanchoes appear to result from a difference in time to floral induction rather than the period from organogenesis to maturation. This response has been observed in dahlias (1), but the variation in days to flowering in chrysanthemum (4) has been related to rate

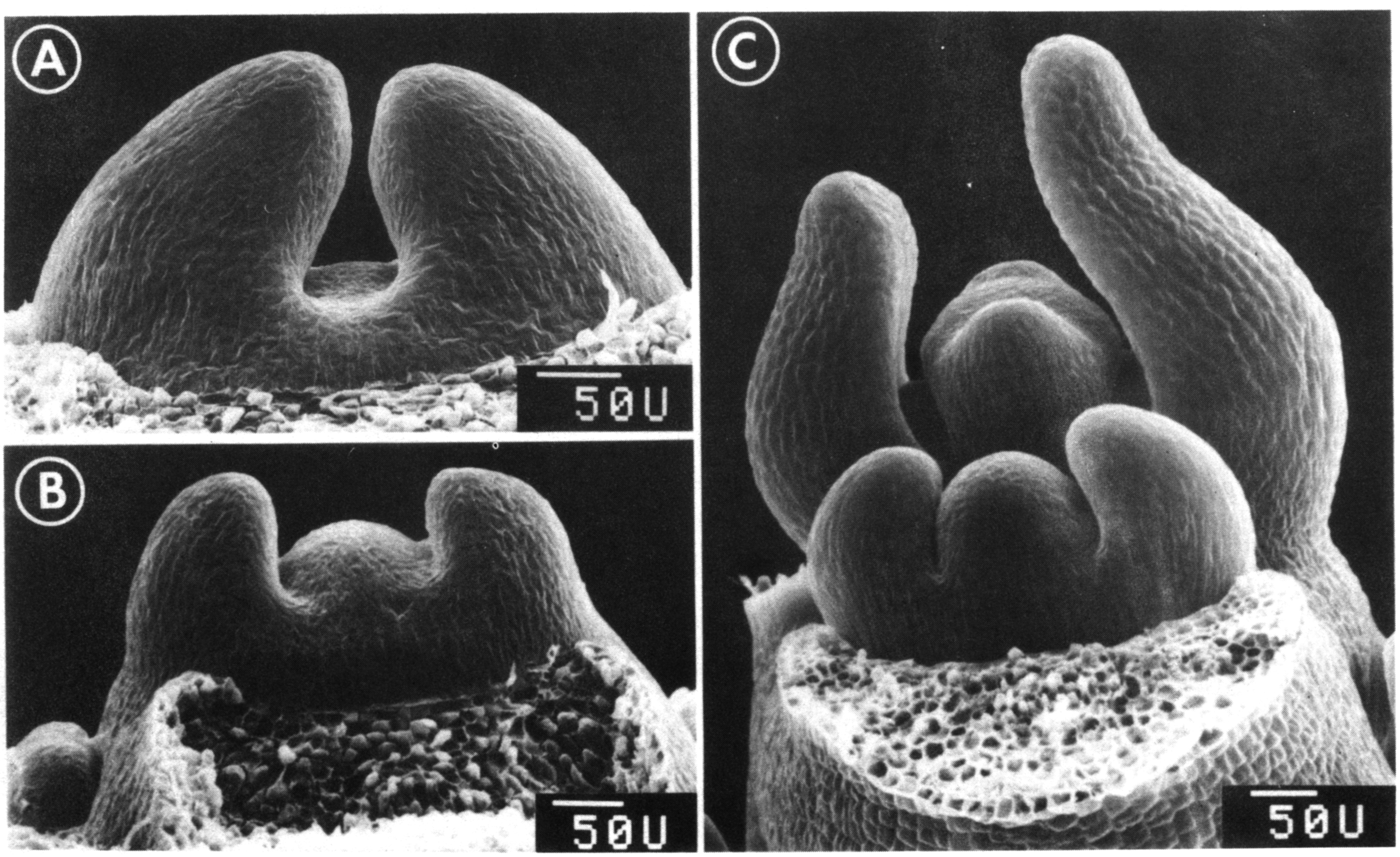

Fig. 1. Scanning electron micrographs of 'Montezuma' kalanchoe showing vegetative and early floral development stages: A) vegetative, B) early reproductive meristem, and C) sepal primordia present in primary flower, axiliary flower present.

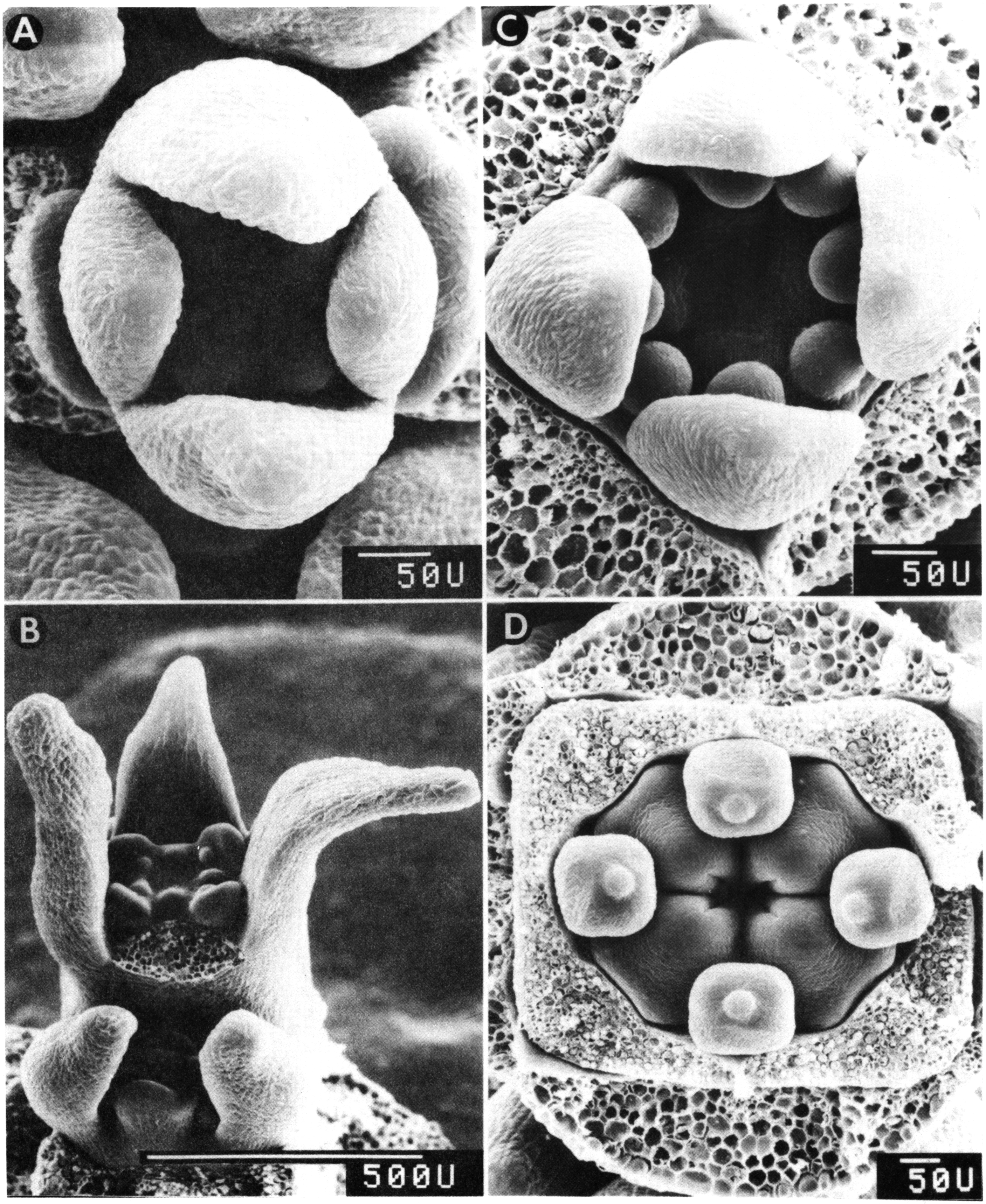

Fig. 2. Scanning electron micrograph of 'Montezuma' kalanchoe showing late floral development stages: A) petal primordia present, B) stamen primordia present, C) petals and stamen elongated, stigma primordia present, and D) stamen elongated, stigma developed, septals and pentals removed.

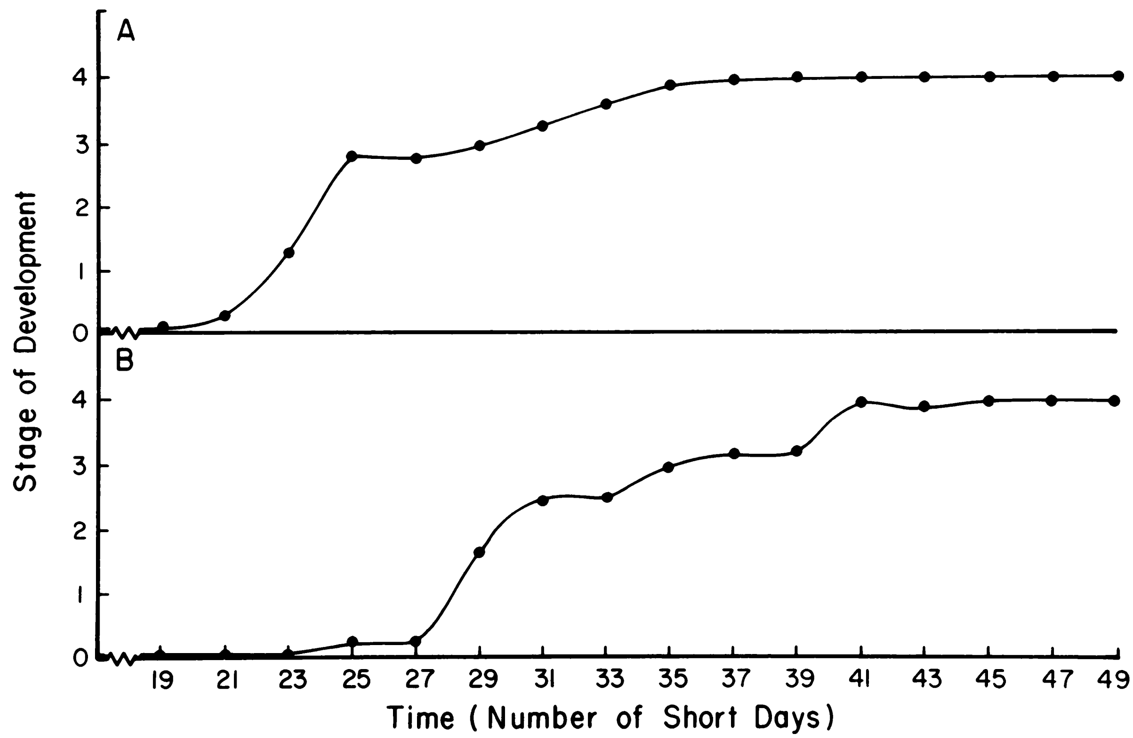

Fig. 3. Floral development of 'Montezuma' and 'Pixie' kalanchoe. A = 'Montezuma', B = 'Pixie'. Developmental stages are 0 = vegetative, 1 = sepal primordia, 2 = petal primordia, 3 = stamen present, and 4 = stigma present.

of development after initiation. Some previous studies have shown that temperature affects the time of anthesis (10, 11), but there has been no work to identify the effect of temperature on the developmental relationships observed in this work.

Literature Cited

1. Barrett, J. E. and A. A. De Hertogh. 1978. Comparative inflorescence development of two cultivars of forced tuberous-rooted dahlia. J. Amer. Soc. Hort. Sci. 103:767–772.
2. Carlson, W. H., C. A. Turner, and J. Schnabel. 1979. Effect of inductive photoperiodic cycles on flowering of kalanchoe cultivars. HortScience 14:62–63.
3. Carlson, W. H., S. Schnabel, J. Schnabel, and C. Turner. 1977. Concentration and application time of ancymidol for growth retardation of *Kalanchoe blossfeldiana* Poellniz. cv. Mace. HortScience 12:568.
4. Doorenbos, J. and A. M. Kofranek. 1953. Inflorescence initiation and development in an early and late chrysanthemum variety. Proc. Amer. Soc. Hort. Sci. 61:555–558.
5. Fredericq, H. 1960. The change of the apex of *Kalanchoe blossfeldiana* towards inflorescence formation. Biol. Jaarb. Dodonaea 28:76–87.
6. Love, J. W. 1980. Kalanchoe. p. 409–434. In: R. A. Larson (ed.). Introduction to floriculture. Academic Press, New York.
7. Mikkelsen, J. 1977. Kalanchoe culture. Ohio Flor. Assoc. Bul. 570:8–9.
8. Nell, T. A. and T. J. Sheehan. 1979. The kalanchoe connection. Amer. Veg. Grower. 27:27.
9. Nightingale, A. E. 1970. The influence of succinamic acid 2,2-dimethylhydrazide on the growth and flowering of pinched vs. unpinched plants of the *Kalanchoe* hybrid 'Mace'. J. Amer. Soc. Hort. Sci. 95:273–276.
10. Pertuit, Jr., A. J. 1977. Influence of temperatures during long-night exposures on growth and flowering of 'Mace', 'Thor', and 'Telstar' *Kalanchoe*. HortScience 12:48–49.
11. Salisbury, F. B. 1969. *Xanthium strumarium* L. p. 14–61. In: L. T. Evans (ed.). The induction of flowering, some case histories. Cornell Univ. Press, Ithaca, N.Y.
12. Schwabe, W. W. 1969. *Kalanchoe blossfeldina* Poellniz. p. 227–246. in: L. T. Evans (ed.). The induction of flowering, some case histories. Cornell Univ. Press, Ithaca, N.Y.
13. Stein, D. B. and O. L. Stein. 1960. The growth of the stem tip of *Kalanchoe* cv. Brilliant Star. Amer. J. Bot. 47:132–140.
14. Turner, C. A. 1980. The effect of night temperatures and photoperiod on flowering in kalanchoe. MS Thesis, Michigan State Univ., East Lansing.