Reprinted from Vol. 108(3), May 1983
Journal of the American Society for Horticultural Science
Alexandria, VA 22314

J. Amer. Soc. Hort. Sci. 108(4):465–468. 1983.

Photographic Analysis of Cucumber Fruit Elongation

Todd C. Wehner and Mikal E. Saltveit, Jr.[1]
Department of Horticultural Science, North Carolina State University, Raleigh, NC 27650

Additional index words. kinematics, *Cucumis sativus*, growth model, fruit length

Abstract. **Growth patterns of cucumbers (*Cucumis sativus* L.) were studied by photographing developing fruit at 2- or 3-day intervals over a 30-day period beginning with pollination (day 0). Nine cultivars were studied: 'Chinese Long Green', 'Sprint 440', 'Marketmore 76', and 'Minisol' (all fresh-market types); 'Riesenschäl' (a schälgurken type); and 'Marbel', 'Kobus', 'Calypso', and 'Wisconsin SMR-18' (all pickling types). Analysis of the photographs showed that all sections of the fruit grew in length at a constant rate during the 30-day period. The pattern of growth was fairly uniform, except that there was slightly more growth in the center section than at the ends, and slightly more growth at the blossom end than at the peduncle end of the fruit. Fresh-market and schälgurken types had the longest fruit over the 30-day period of growth, but pickling types had the highest percent change in length. Pickling types produced shorter fruit because they stopped growing earlier than the two other types (12 vs. 14 days, respectively).**

Fruit size and shape are important considerations in cucumber breeding programs. For best quality, fresh-market cucumbers to be grown for field production in the United States should be long and narrow: greater than 152 mm in length and less than 60 mm in diameter (9). In contrast, pickling cucumbers to be grown for field production in the United States should be short and cylindrical with a length about 3 times the diameter. Fruit greater than 51 mm in diameter are usually not salable.

Sinnott (8) found that fruit shape in several *Cucurbita* species was related to the orientation of cell division. According to his findings, one would expect the plane of cell division to be mainly perpendicular to the long axis of a cucumber fruit. The exception would be the spherical fruit that develop from hermaphroditic flowers, where a random orientation of the plane of cell division would be expected.

Growth of cucumber fruit was first noticeable 24 hr after pollination (4), and the most rapid increase in length occurred

Received for publication July 6, 1982. Paper No. 8410 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of products named, nor criticism of similar ones not mentioned. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Present address: Dept. of Vegetable Crops, Univ. of California, Davis, CA 95616.

Table 1. Fruit length of 9 cultivars of cucumbers, 2 to 30 days after pollination.

	Fruit length (mm)								
	Fresh-market				Pickling				
Days	Chinese Long Green	Sprint 440	Marketmore 76	Minisol	Riesenschäl	Marbel	Kobus	Calypso	Wisconsin SMR-18
2	46	36	31	49	41	30	27	28	29
4	83	63	50	75	64	48	53	52	66
7	150	131	95	132	121	93	111	105	98
9	200	174	134	175	161	114	135	131	137
11	224	202	162	208	195	130	154	152	160
14	252	224	183	225	223	133	161	162	182
16	257	229	188	230	228	135	166	164	185
18	267	236	195	231	233	138	168	167	190
21	271	241	202	237	243	138	170	170	195
23	275	244	204	238	247	139	172	170	195
25	275	244	206	240	248	139	172	170	196
28	275	247	210	245	253	139	175	171	198
30	276	249	210	245	254	139	175	171	199
LSD 5% = 32[z]									

[z]For comparison among both rows and columns; CV = 12%.

in the 4th through 12th day after anthesis (5). Growth in length reached a peak about 20 days after anthesis in pickling cucumber fruit (5). Therefore, we chose to study cucumber fruit growth during the 30 days following pollination.

We analyzed growth patterns to determine whether fruit growth occurs at the stem end, middle section, or blossom end, or whether it occurs uniformly over the whole fruit. The method used was a hybrid between the classical experimental methods of Sachs (6), who used evenly spaced dots on the root of a maize (*Zea mays* L.) seedling, and the photographic methods of Erickson et al. (1, 2, 3, 7). The objective of this experiment was to determine where the growth fields of cucumber fruit were located for several different fruit types.

Materials and Methods

Nine cultivars were chosen to represent diverse cucumber types. Four were fresh-market types: 'Chinese Long Green' (monoecious), 'Sprint 440' (gynoecious hybrid), 'Marketmore 76' (monoecious), and 'Minisol' (gynoecious hybrid). One was a schälgurken: 'Riesenschäl' (monoecious). Four were pickling types: 'Marbel' (gynoecious hybrid), 'Kobus' (gynoecious hybrid), 'Calypso' (gynoecious hybrid), and 'Wisconsin SMR-18' (monoecious).

Growth of cucumber fruit was analyzed in one dimension by adapting Erickson's (1) method for studying root growth. Plants were grown in the greenhouse in Spring 1981. Seeds of the 9

Table 2. Percent change per day in length of fruit of 9 cultivars of cucumber, 2 to 30 days after pollination.

	Fruit-length change (% per day)								
	Fresh-market				Pickling				
Days	Chinese Long Green	Sprint 440	Marketmore 76	Minisol	Riesenschäl	Marbel	Kobus	Calypso	Wisconsin SMR-18
2	---	---	---	---	---	---	---	---	---
4	40.2	37.5	30.6	26.5	28.0	30.0	48.1	42.9	63.8
7	26.9	36.0	30.0	25.3	29.7	31.2	36.4	34.0	16.2
9	16.7	16.4	20.5	16.3	16.5	11.3	7.2	12.4	19.9
11	6.0	8.0	10.4	9.4	10.6	7.0	7.0	8.0	8.4
14	4.2	3.6	4.3	5.7	4.8	0.8	1.5	2.2	4.6
16	1.0	1.1	1.4	2.5	1.1	0.8	1.6	0.6	0.8
18	1.9	1.5	1.9	0.5	1.1	1.1	0.6	0.9	1.4
21	0.5	0.7	1.2	2.0	1.4	0.0	0.4	0.6	0.9
23	0.7	0.6	0.5	0.5	0.8	0.4	0.6	0.0	0.0
25	0.0	0.0	0.5	1.0	0.2	0.0	0.0	0.0	0.3
28	0.0	0.4	0.6	1.7	0.7	0.0	0.6	0.2	0.4
30	0.2	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.3
LSD 5% = 2.4[z]									

[z]For comparison among both rows and columns; CV = 28%.

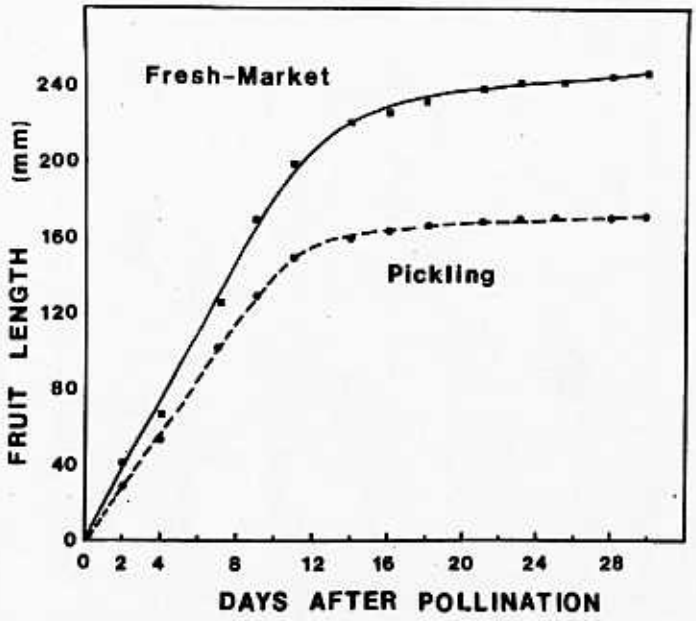

Fig. 1. Growth of fresh-market and pickling cucumber fruit. Each point on the fresh-market curve represents the mean of the length of 3 fruit of 'Minisol', 'Chinese Long Green', 'Marketmore 76', 'Sprint 440', and 'Riesenschäl' (actually a schälgurken pickling type), while each point on the pickling curve represents the mean of the length of 3 fruit of 'Marbel', 'Kobus', 'Calypso', and 'Wisconsin SMR-18'.

cultivars were planted May 26 in peat pots containing a standard soil mix of 1 soil : 1 sphagnum peatmoss : 1 sand (by volume). Seedlings were transplanted at the cotyledon stage to 15-cm diameter plastic pots. Additional plants of each gynoecious line were grown nearby as a pollen source, and were sprayed with silver nitrate at the cotyledon stage to induce staminate flower formation. Plants were grown under standard greenhouse conditions with daily watering, regular fertilization, and application of pesticides to control insects and diseases. Temperature was maintained at 27°C (day) and 21° (night). Flowers were pollinated on 55-day-old plants, and measurements of developing fruit made from July 22 to August 19.

Spots of India ink were placed at regular intervals on ovaries 2 days after they were pollinated. It was necessary to wait 2 days to make sure that the ovaries were developing normally. Fruit that developed without observable defects were photographed at 2- or 3-day intervals from day 2 to day 30. Photographs were taken on the same day that fruit length was measured using a Canon AT-1 35-mm single-lens reflex camera and a 50-mm f3.5 macrolens. The film was Kodak Panatomic-X. A Canon Databack A was used to mark each frame of the film during exposure with the replication number, number of days after pollination, and line number. Decreasing lens magnification was used as the fruit increased in length to keep the developing fruit a constant size on the negative. This was done to make it easy to produce prints of the same size for analysis of growth fields. Contact prints were made and individual frames mounted on a large poster board for initial organization and study. Enlargements were made of selected photographs so that the fruit length on each print was 154 mm.

The experiment was a completely random design with 3 replications. Fruit-length data was subjected to an analysis of variance, and the Waller-Duncan least significant difference (LSD) was calculated for comparison of means using a "k" ratio of 100:1.

Results and Discussion

Comparisons of fruit length of all cultivars indicated that there was little growth after the 14th day from pollination, and that growth could be portrayed accurately using only 5 or 6 photographs (dates) rather than all 13 for each cultivar.

Of the 9 cultivars studied, 'Chinese Long Green' had the longest fruit 30 days after pollination (Table 1). The fresh-market cultivars and the schälgurken type ('Riesenschäl') had longer fruit than the pickling cultivars at all stages. They started out longer and maintained their growth rate for a longer period of time.

The greatest percent change in fruit length per day occurred in the first few days after pollination (Table 2). Pickling cultivars had a greater percent change than the schälgurken type and the fresh-market cultivars, and 'Wisconsin SMR-18' had the largest percent change of all cultivars. 'Minisol', the cultivar with the largest fruit on day 2 (Table 1), had the lowest initial percent change of all cultivars, and the lowest overall change of the schälgurken and the fresh-market cultivars (Table 2).

In agreement with the report by Hammett et al. (5), cucumber fruit increased in length through the 12th day after pollination for the pickling types before ceasing (Fig. 1). For fresh-market and schälgurken types, growth continued through the 14th day. The latter types had longer fruit than pickling types, not because of higher growth rates, but because they grew for a longer period of time. The growth rates of the 2 types, as shown by the slope of the growth curves, were approximately the same (Fig. 1).

Photographs of developing fruit of 2 of the 9 cultivars used in this study are shown in Fig. 2. 'Kobus' represents the growth habit of the pickling cucumbers, while 'Marketmore 76' represents the fresh-market cucumbers. A major difference between root growth [as described by Erickson (2)] and fruit growth was that the fruit became blunt at the ends as their length increased, causing dots near the end to disappear around the end. Thus, from the side, the dots appear to be closer to the end than they really are.

The photographs were enlarged so that fruit in all prints are the same length (154 mm) and each print was located on the y-axis according to the actual length of the fruit (Fig. 2). This permitted analysis of growth fields for 2 characteristics. First, if lines drawn between identical spots on each of the 5 or 6 prints of the developing fruit are parallel, then fruit growth between those lines was uniform in comparison to the growth of the whole fruit. Second, if the line through the same ink spot on each print is straight, then growth in that area was constant in relation to growth of the whole fruit.

According to those criteria, growth of the fresh-market and pickling cucumbers studied in this experiment occurred fairly evenly over all parts of the fruit. However, growth was slightly greater in the center section of the fruit than on the ends, and slightly greater on the blossom end than on the peduncle end (Fig. 2). Furthermore, growth was uniform over the whole fruit, since most of the lines run fairly straight through the spots on the 5 or 6 successive prints. These results are in agreement with a preliminary study made on 6 lines of pickling and fresh-market cucumbers in the greenhouse in the spring of 1981 (data not shown).

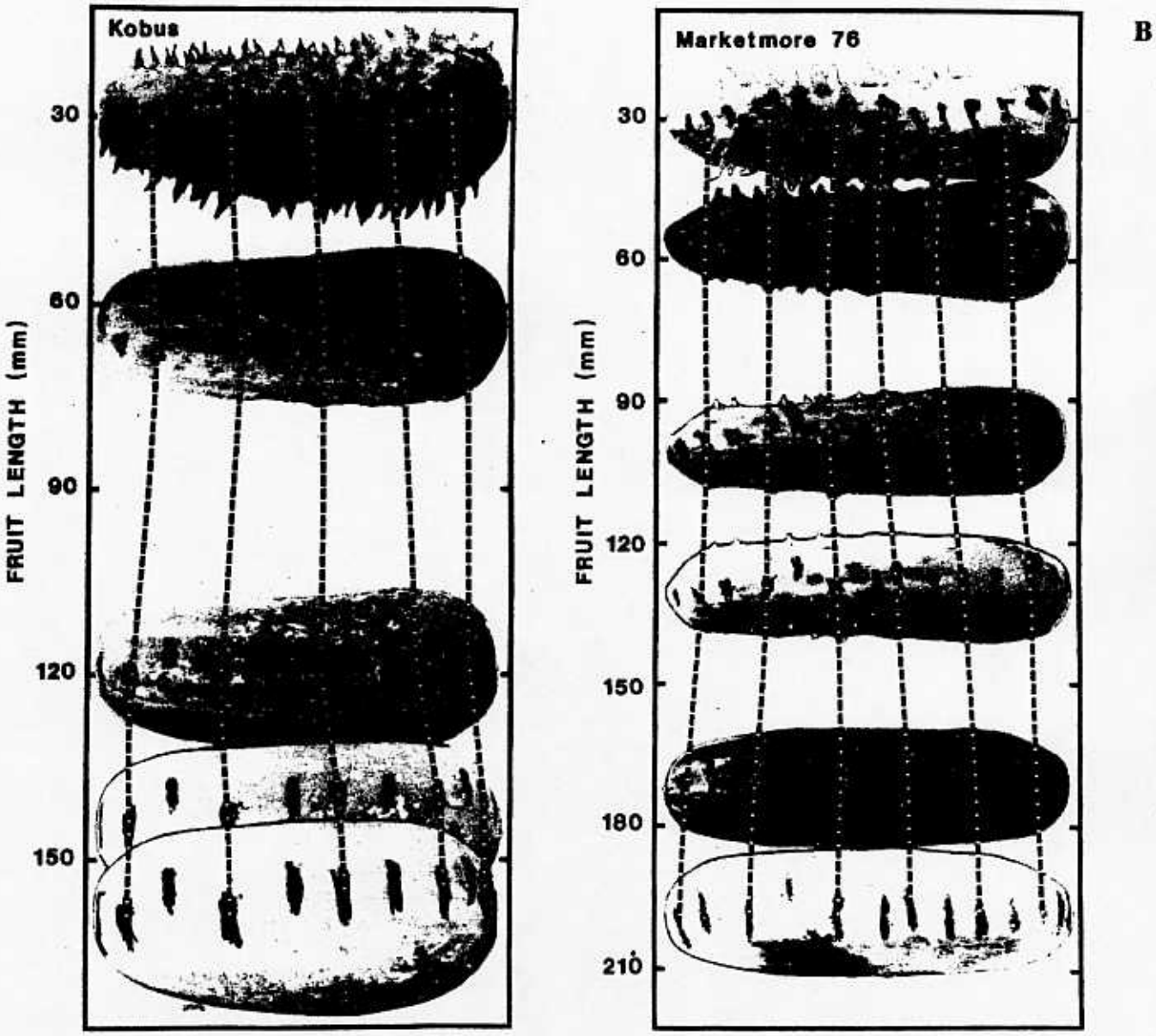

Fig. 2. Growth fields of 'Kobus' fruit 2, 4, 7, 11, and 28 days after pollination, respectively, (A) and 'Marketmore 76' fruit 2, 4, 7, 9, 14, and 28 days after pollination, respectively, (B) are shown by vertical lines.

Literature Cited

1. Erickson, R.O. 1976. Modeling of plant growth. Annu. Rev. Plant Physiol. 27:407–434.
2. Erickson, R.O. and K.B. Sax. 1956. Elemental growth rate of the primary root of *Zea mays*. Proc. Amer. Phil. Soc. 100:487–498.
3. Erickson, R.O. and W.K. Silk. 1980. The kinematics of plant growth. Sci. Amer. 242:134–151.
4. Fuller, G.L. and A.C. Leopold. 1975. Pollination and the timing of fruit-set in cucumbers. HortScience 10:617–619.
5. Hammett, H.L., R.C. Albritton, W.A. Brock, S.P. Crockett, and B.E. Waggoner. 1974. Production of cucumbers for pickles. Miss. Agr. For. Expt. Sta. Bul. 801.
6. Sachs, J. 1873. Uber das Waschsthum der Haupt- und Nebenwurzeln. Arb. Bot. Inst. Wurzeb. 1:385–474.
7. Silk, W.K. and R.O. Erickson. 1979. Kinematics of plant growth. J. Theor. Biol. 76:481–501.
8. Sinnott, E.W. 1944. Cell polarity and the development of form in cucurbit fruits. Amer. J. Bot. 31:388–391.
9. U.S. Agricultural Market Service. 1958. United States standards for cucumbers. U.S. Government Printing Office, Washington, D.C.