THESIS

FRUIT GROWTH IN CUCUMBERS

Submitted by

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In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

April, 1977

COLORADO STATE UNIVERSITY

April, 1977

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY AHMED TAHER ELFIGIH ENTITLED FRUIT GROWTH IN CUCUMBERS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

FRUIT GROWTH IN CUCUMBERS

A. Growth Differences Between Genetically Parthenocarpic Seeded (Pollinated) and Seedless (Not Pollinated) Fruits

Fruit growth in all cases was sigmoidal. The rate and duration of growth were essentially the same in both varieties and whether or not pollinated.

Genetically parthenocarpic cultivars produced less fresh fruit weight when pollinated than when not pollinated, but the t-test showed the differences to be non-significant.

B. Growth Differences Between Genetically Short- and Long-Fruited Lines and Varieties

Growth in all types was again sigmoidal. The long- and short-fruited types grew at essentially the same rate but for different durations.

Overall correlation between ovary length at blooming and mature fruit length for long, medium and short-fruited cucumber was 0.97. This suggests that long-fruited types will have longer ovaries.

No cell division occurred in ovaries after pollination. This suggests that cell division ceases at or shortly after anthesis and the subsequent fruit growth is due to cell enlargement rather than cell number.

The analysis of variance for cell size and cell number in mature fruits of long-, medium- and short-fruited varieties showed highly significant differences between varieties between regions and their interaction.

An inverse relationship existed between cell volume and cell number; cell volume increased toward the inner part of the fruit in all types.

Differences in fruit size are usually due to differences in both cell number and cell size.

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April, 1977

ACKNOWLEDGMENTS

I am especially indebted to Dr. D. W. Denna for his advice and assistance in outlining and conducting this study until the time of his death. His spirit and kindness will not be forgotten. My sincere appreciation to Dr. M. Workman, my major professor, for his assistance and his critical review of this thesis.

Special thanks to Dr. T. Tsuchiya, Professor of Agronomy, for his assistance in the cytogenetic aspects of this study.

I would like to thank Dr. D. R. Wood, Professor of Agronomy, and Dr. C. W. Basham, Assistant Professor of Horticulture, for their suggestions and criticisms in preparing the thesis.

My thanks to C. Nakamura, graduate student in Agronomy, for his help in the use of the microscope and darkroom facilities.

Thanks are extended to my friend, S. Moomen, graduate student in forestry, for his help and encouragement.

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CHAPTER I

INTRODUCTION

The cucumber is an important vegetable crop in most parts of the world, being grown in the home gardens, market gardens, vegetable farms, and as a forcing crop in greenhouses, or as a special crop for pickles.

Cucumbers are picked on the basis of size rather than age. The high cost of labor, high economic values and short harvest periods are encouraging growers to depend on machines for harvesting cucumbers. Mechanical harvesting of cucumbers has brought the need for cultivars and cultural methods which maximize yield in a single harvest. Changes in cultural procedures such as narrow rows and high plant populations are necessary for profitable yields. There is much emphasis on variety improvement in terms of uniform maturity, size, and gynoecious flowering habit in which the plant produces pistillate flowers; the use of parthenocarpic varieties would eliminate the need for interplanting monoecious cultivars with the gynoecious cultivars to ensure pollination and it will permit the culture of entirely gynoecious population.

To facilitate further research studies with cucumbers, fruit growth in cucumbers appear to be important. Objectives of this study were as follows:

1. To determine the growth differences between genetically parthenocarpic seeded (pollinated) and seedless (not pollinated) fruits.

2. To determine the growth differences between genetically short- and long-fruited lines and varieties.

CHAPTER II

REVIEW OF LITERATURE

Fruit Growth

Growth is the increase in the various components of the organism. This results from the cell division and elongation. Fruits have a determinate growth, the meristems are diffuse, so that the whole organ is growing throughout and not at any particular point (26).

Studies have been made of the growth of fruits. Anderson (1) brought a young pumpkin fruit into the laboratory, still attached to the vine and weighed it for a period of 47 days. Growth showed a sigmoid curve. Gustafson (5) studied the growth of a number of cucurbit fruits, with results much like Anderson's.

Gross Size Differences

Sinnott (25) found that final fruit size has little relation to rate of growth, but is determined chiefly by its duration. In large-fruited races, each portion of the growth cycle is of longer duration than in small-fruited races. Also, there are slight inherited differences in growth rate between the various lines of cucurbits. Sinnott suggested that genetic factors for fruit size may operate by controlling the production or destruction of physiologically active substances such as vitamins and hormones necessary for fruit growth. Maltzahn (14)

studied two strains of Cucurbita pepo L. which differ greatly in their size and found the growth pattern of the two strains to be the same.

Cellular Size Differences

Fruit size differences in cucurbits are usually due to differences in both cell size and cell number, although either one may be responsible in certain cases (24). Maltzahn (14) found that the difference in size of vegetative structures between large and small races of Cucurbita was due to both cell size and cell number. Houghtaling (9) showed that early fruit growth of tomato is due to cell multiplication and later growth entirely to cell expansion; the extent of both these processes was greater in large fruits than in small fruits. MacArthur and Butler (13) reported similar results.

Seed in Relation to Size Differences

Tomato fruit weight is influenced by the number of seeds produced within fruit (8, 21). Similar results with strawberry has been reported by Janick and Eggert (10) and with cranberry by Hall and Aalders (7). Darrow (4), with blueberry, and Moore, Brown and Brown (15), with strawberry, found that large fruit had more seeds than small fruit. This is due to differential activity of achenes in producing growth hormones and differential sensitivity of receptacular tissue to the growth hormones (15).

It appears that fruit size in the blueberry is partially determined by the number of developed seed and their production of growth

hormones. Thus, several genetically controlled factors seem to influence fruit size development in the blueberry. Seed size is not related to fruit size in the blueberry (16).

Crane (2) reported that seeds are rich in auxins, gibberellins and cytokinins which stimulate fruit growth and also control fruit abscission.

Genetics of Sex Expression in Cucumber

The genetics of sex expression in cucumber is determined by two major genes plus modifiers. A single recessive gene is responsible for the andromonoecious (bisexual flowers and male flowers), a dominant gene governs gynoecious (only female flowers) or gynomonoecious (mostly female flowers, few male flowers). Plants homozygous for both genes have perfect flowers, and plants with the normal allele of each gene are monoecious (male flowers and female flowers on the same plant). When hybrids are desired, a gynoecious line is preferable as the female parent since it cannot self-pollinate, and thus, all the seed it produces will be hybrid. A gynoecious line may be perpetuated by treatment with a growth regulator to induce it to produce staminate flowers, or by crossing it with an isogenic line having perfect flowers (22).

Parthenocarpy

Parthenocarpy is the development of fruit without fertilization. It occurs naturally in a number of horticultural varieties of bananas,

pineapples, cucumbers, tomatoes, figs, and by a variety of means has been induced in others.

Strong (27) tested 34 cucumber cultivars in the greenhouse over a period of four years. All produced some parthenocarpic fruits, but a few cultivars produced many more seedless fruits than others. Whitaker (30) suggested that the process is at least partially under genetic control. Gustafson (6) induced parthenocarpy in cucurbits through application of growth substances to the pistil. He also observed that naturally parthenocarpic fruit had higher auxin concentration than seed-bearing fruit.

Nitsch, et al. (17) reported that parthenocarpic female flowers were obtained with the "Boston pickling" cucumber by exposure to short days (12 hr or less) and cool nights (17^{o}C or less).

How the growth of these seedless fruit is controlled is not understood, but it is possible that the maternal tissues such as the placenta, may be capable of producing auxin in the absence of normal embryos (29).

Pike and Peterson (20) reported the inheritance of parthenocarpy in cucumber to be conditioned by an incomplete dominant gene P. In the homozygous condition PP produced parthenocarpic fruits early; heterozygous Pp plants produce parthenocarpic fruits later than homozygous plants and fewer in number, while the homozygous recessive pp produces no parthenocarpic fruits.

Robinson and Whitaker (22) suggested that the gene governing parthenocarpy in cucumber originated as a spontaneous mutation in the last century, and was perpetuated by European horticulturists because of its beneficial effect on yield in greenhouses where insects are scarce. There has been renewed interest in the parthenocarpic gene because of development of gynoecious cultivars that otherwise need to be grown with monoecious plants for pollination. The current practice of blending seed of monoecious pollinator with seed of a gynoecious hybrid can be replaced by breeding the parthenocarpic gene into the gynoecious cultivar. Kooistra (12) combined gynoecious sex expression from MSU 713-5 with parthenocarpy from European greenhouse varieties. Peterson (18) developed the gynoecious cucumber line MSU 713-5. Peterson and Anhder (19) maintained such lines by inducing staminate flowers with gibberellic acid.

Denna (3) found that genetically parthenocarpic cultivars produced significantly less fruit fresh weight when pollinated (seeded) than without pollination (seedless).

Pike and Peterson (20) believed that parthenocarpic, gynoecious pickling cucumbers will be advantageous for mechanical harvesting because of greater fruiting capacity, slower fruit maturity, and the elimination of the need for pollinating insects.

Denna (3) expressed the same opinion and suggested that the smaller mature fruit size and determinate growth habit together with parthenocarpy and gynoecious flowering should maximize fruit

production for single harvesting, produce a high fruit to vine ratio, and provide flexibility in harvesting timing.

CHAPTER III

MATERIALS AND METHODS

The organization of this chapter will follow the objectives as presented in the introduction.

Experiment I

Growth Differences Between Genetically Parthenocarpic Seeded (Pollinated) and Seedless (Not Pollinated) Fruits:

--Plant Materials:

Two genetically gynoecious, parthenocarpic European greenhouse cultivars, Toska 70 and Rocket, were used in the parthenocarpic studies; these were obtained from Stokes Seeds, St. Catharines, Ontario, Canada.

--Growing Conditions and Methods:

Seeds of each variety were planted initially in individual peat pots and the seedlings were selected for uniformity before transplanting into two greenhouse soil benches; the seedlings were randomly transplanted.

The greenhouse was equipped with evaporative coolers, the approximate day and night temperatures were 28°C and 22°C, respectively.

The main stem of each plant was trained vertically on binder twine.

Before the pollination and non-pollination treatments, mature female blossoms were removed daily until the plants developed 6 large leaves; this was to allow the plant to develop the potential to produce fruits at the same time.

Since the two cultivars used in Experiment I were entirely gynoecious (all female flowers) and parthenocarpic, male flowers from the plants of Experiment II were used to pollinate the flowers of the pollinated treatments. The flowers of the pollinated and non-pollinated treatments were tagged on the day of opening. The date of tagging was considered to be day zero; two to three fruits were allowed to grow on each plant.

The width and length of each tagged fruit was taken every other day beginning on the day the female flower opened and continued until fruit growth ceased; callipers and ruler were used for these measurements.

The assumption that the greenhouse remained free of pollinating insects was verified by the absence of seeds in the fruits of non-pollinated cultivars.

Fresh weight and dry weight of each tagged fruit were taken; fruits were sliced and dried in a forced air drying oven at $70^{\circ}C$ for 3 days.

Experiment II

Growth Differences Between Genetically Short- and Long-Fruited Lines and Varieties:

--Plant Materials:

Seed of plant introduction "PI 271328" (short-fruited) was obtained from the plant introduction station at Ames, Iowa. Seed of Marketmore (medium-fruited) and Japanese long pickling (long-fruited) were obtained from Stokes Seeds, St. Catharines, Ontario, Canada.

--Growing Conditions and Methods:

Same as in Experiment I, in the same greenhouse, but transplanted into two other soil benches, and all the tagged flowers were pollinated.

Cytological Techniques

A. Mitotic Studies:

Four ovary maturities were studied:

1. very young ovaries
2. young ovaries
3. ovaries of flowers on the day they opened
4. after pollination.

Sections were fixed for 48 hours at room temperature in 3:1 mixture of 95% ethanol and glacial acetic acid, 2% iron alum mordant was added. Sections were stained for 2 or more days at room temperature in 0.8% acetocarmine. The materials were squashed in

dilute acetocarmine or 45% acetic acid (27). Photomicrographs of the dividing cells were taken with the Zeiss photomicroscope II.

B. Cell Size and Cell Number Studies:

Standard cytological methods (22, 11) were used. Sectors of mature fruits from the outside to the center of PI 271328, Marketmore, and Japanese long pickling were collected and fixed in Nawaschin's solution (CRAF II) for 48 hours at room temperature. The following graded ethanol series was used to dehydrate the tissues: 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 95, and absolute ethanol. The ethanol-xylene clearing series consisted of solutions with respective parts of ethanol and xylene as follows: 3:1, 1:1, 1:3, and 0:1. The tissues were infiltrated and embedded in paraffin. The embedded material was mounted on plastic blocks. Cross sections and longitudinal sections were taken with a rotary microtome. Twenty micron sections were used in this study. Sections were affixed to slide with Haupt's adhesive and stained with Mayer's hematoxylin. Cover slips were mounted using permount mounting medium.

The stained slides were studied with a phase microscope. Photomicrographs were taken with the Zeiss photomicroscope II, and enlarged to 340 times. Cell length and width measurements were made with a ruler. Actual cell measurements in micron were calculated as follows:

cell length or width (microns) =

$$\frac{\text{cell length or width in cm (from photomicrograph)} \times 10^4}{340}$$

where 10^4 converts cm to microns.

340 is the magnification of the photomicrograph.

In all varieties studies in Experiment 2, there is a gradient in cell size from the inside of the fruit outward, the cells growing progressively smaller toward the epidermis.

The cucumber is a berry fruit called a pepo. The ovary wall or pericarp is composed of three layers: from outer to inner layer, the exocarp, mesocarp and endocarp. Since most of the fruit consists of the mesocarp layer, the mean cell volume from this layer can be taken as the volume of cells contributing most to the fruit size. Cell measurements were taken from both longitudinal and transverse sections in a region of the mesocarp layer about 762 μ thick (Figures 13 and 14) and these sections were divided into 3 regions:

Region 1: Adjacent to the epidermis region, has the smallest cells, is about 174 μ thick.

Region 2: Adjacent to Region 1, has medium cell size, is about 294 μ thick.

Region 3: Adjacent to Region 2, has larger cells than the other two regions, is about 294 μ thick.

Since the form of the cells approximated an ellipse, cell volume for each region was calculated with the formula $\frac{4}{3}\pi abc$ where a and b are half the length of the major and minor axes of the cross section, and c is half the length of the minor axis of the longitudinal section.

For purpose of comparison, cell number for each region was calculated as follows:

$$\text{Cell number} = \frac{\text{Region volume}}{\text{cell volume in the region}}$$

Since the form of Japanese long and Marketmore approximated a cylinder, fruit volume was calculated by using the formula $\pi r^2 L$, where r is the fruit radius and L is the fruit length. Fruit form of the PI 271328 was considered approximately as ellipsoid, the volume was calculated by using the formula $\frac{4}{3}\pi r^2 h$ where r is the fruit radius and h is half its length. From the total fruit volume and the volume of unsampled portion of the fruit, the volume of each region may be calculated.

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I

Growth Differences Between Genetically Parthenocarpic Seeded (Pollinated) and Seedless (Not Pollinated) Fruits:

Fruit Growth in General. --The data for increase in length and width of pollinated and not pollinated fruit of Toska 70 and Rocket from flowering to maturity are presented in Table 1a and 1b; for clarity, the data are plotted against time in Figure 1 through Figure 4.

A comparison between pollinated and not pollinated fruit in each variety shows that growth in all cases consists of an initial phase (Lag phase), then a rapid increase phase (linear phase), and finally, a slowing down until growth ceases when the fruit is fully mature.

When the log of the length and width are plotted against time, growth follows a straight line initially, but later declines (Figures 5 and 6). From this plot, a better comparison of fruit growth of pollinated and not pollinated varieties is possible. In each fruit type, the growth consists of two phases: an initial phase having a constant exponential rate (straight line), followed by a final phase

Table 1a. Growth and percentage of total growth of Toska 70 fruit from flowering to maturity.

Variety	Time Days	Length				Width			
		Pollinated	%	Not Pollinated	%	Pollinated	%	Not Pollinated	%
Toska	0	5.20	13	5.16	13	0.62	9	0.66	11
	2	6.43	17	6.62	17	0.80	12	0.70	11
	4	8.52	22	8.80	23	1.00	15	0.90	15
	6	12.25	32	12.90	33	1.40	21	1.30	21
	8	17.10	44	18.10	46	2.10	32	2.00	32
	10	19.50	50	23.70	61	3.00	45	2.70	44
	12	27.70	72	28.00	72	3.80	58	3.40	55
	14	30.90	80	31.80	81	4.50	68	4.10	66
	16	32.80	85	34.00	87	5.00	76	4.60	74
	18	34.00	88	34.60	88	5.40	82	5.00	81
	20	35.20	91	35.70	91	5.70	86	5.20	84
	22	35.70	92	36.80	94	6.00	91	5.40	87
	24	36.90	95	37.60	96	6.20	94	5.50	89
	26	37.90	98	38.30	98	6.40	97	5.60	90
	28	38.30	99	38.60	99	6.50	98	5.70	92
	30	38.40	99	38.80	99	6.50	98	5.90	95
	32	38.70	100	39.10	100	6.60	100	6.20	100
	34	38.70	100	39.10	100	6.60	100	6.20	100

Table 1b. Growth and percentage of total growth of Rocket fruit from flowering to maturity.

Variety	Time Days	Length				Width			
		Pollinated	%	Not Pollinated	%	Pollinated	%	Not Pollinated	%
Rocket	0	5.30	15	5.30	15	0.54	9	0.56	10
	2	5.40	15	5.40	15	0.66	12	0.68	12
	4	6.80	18	7.40	20	0.78	14	0.80	14
	6	9.30	25	10.10	27	0.98	17	1.00	18
	8	13.80	37	14.70	40	1.42	25	1.50	26
	10	18.80	51	19.30	52	2.00	35	2.00	35
	12	24.00	65	26.30	71	2.70	47	2.80	49
	14	28.00	76	30.20	81	3.34	59	3.50	61
	16	29.80	81	32.00	86	3.80	67	3.90	68
	18	31.80	86	33.10	89	4.20	74	4.40	77
	20	32.70	88	33.60	91	4.60	81	3.60	81
	22	34.20	92	34.80	94	4.90	86	4.80	84
	24	34.80	94	35.70	96	5.20	91	5.00	88
	26	35.40	96	36.10	97	5.40	95	5.30	93
	28	36.00	97	36.50	98	5.58	98	5.40	95
	30	36.50	99	36.90	99	5.60	98	5.50	96
	32	37.00	100	37.10	100	5.70	100	5.60	100
	34	37.00	100	37.10	100	5.70	100	5.60	100

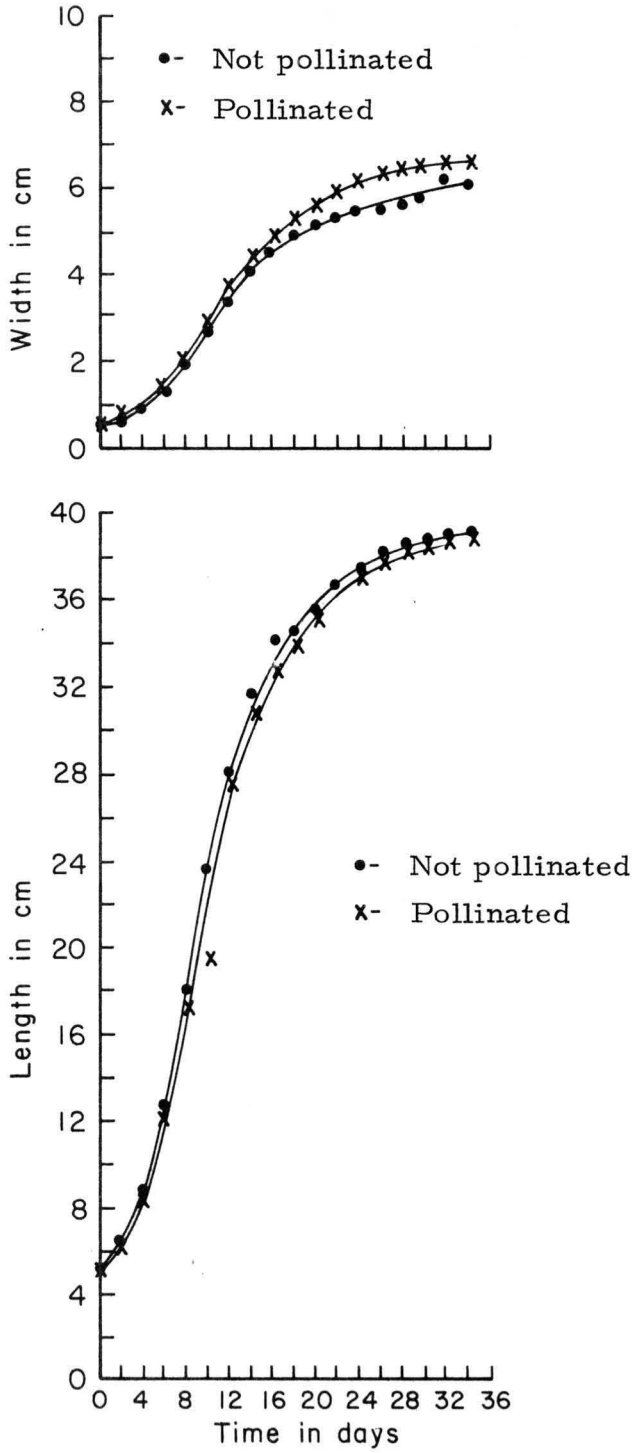


Figure 1. Sigmoid growth curves of Toska 70 pollinated and not pollinated fruits from flowering to maturity. Upper: fruit width; lower: fruit length.

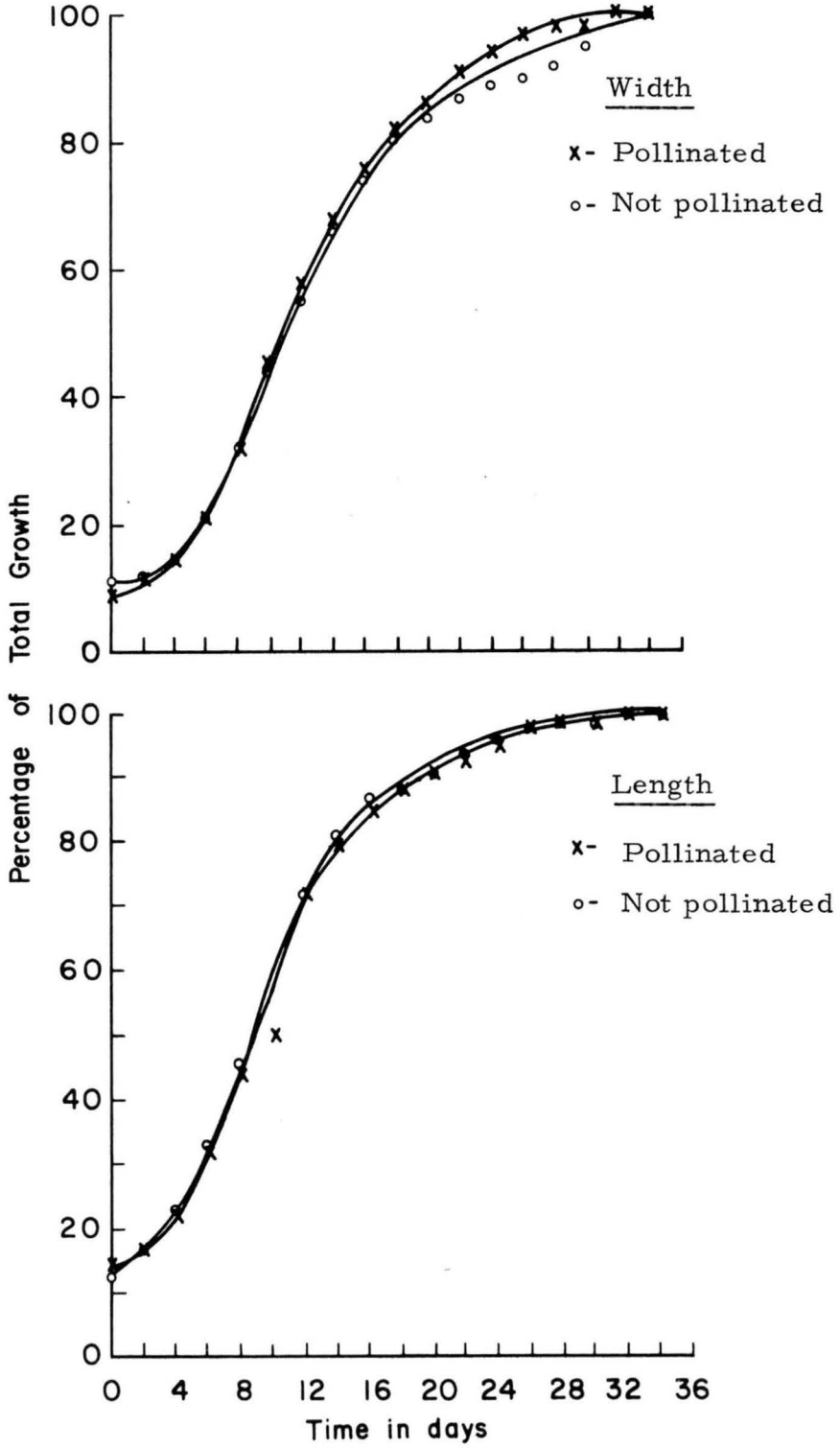


Figure 2. Sigmoid growth curves in percentage for Toska 70 pollinated and not pollinated fruits from flowering to maturity. Upper: fruit width; lower: fruit length.

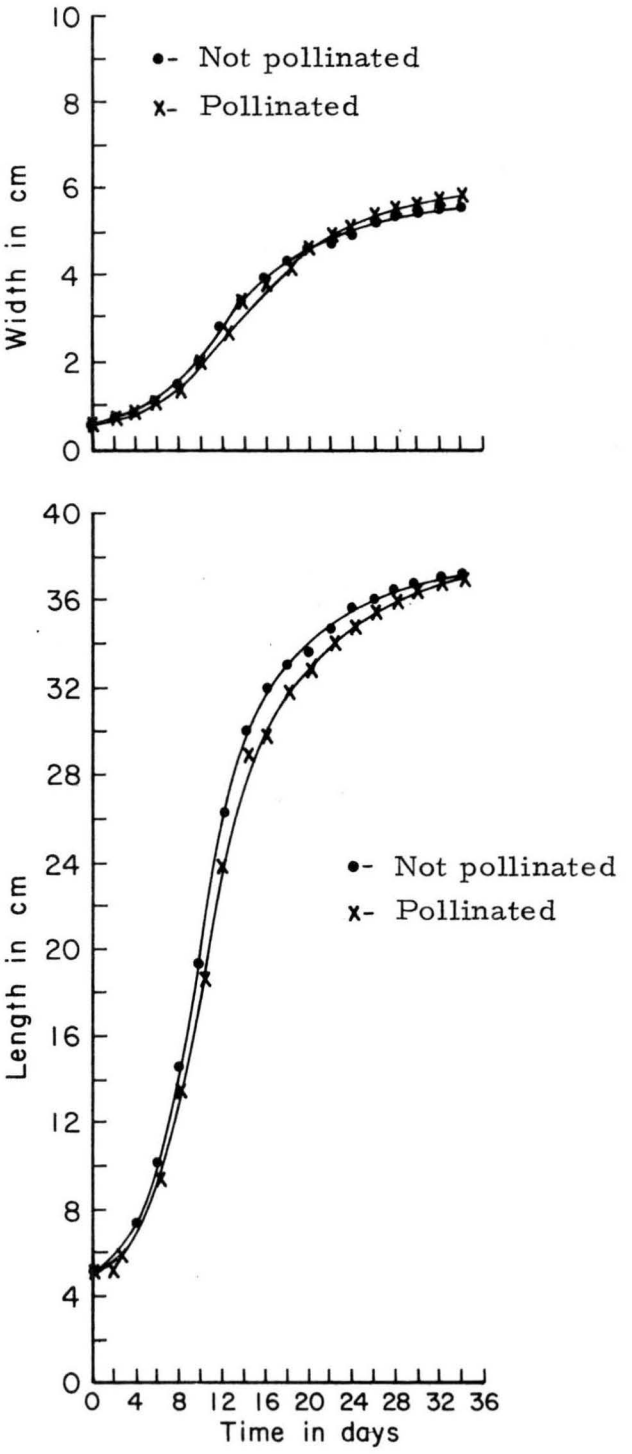


Figure 3. Sigmoid growth curves of Rocket pollinated and not pollinated fruits from flowering to maturity. Upper: fruit width; lower: fruit length.

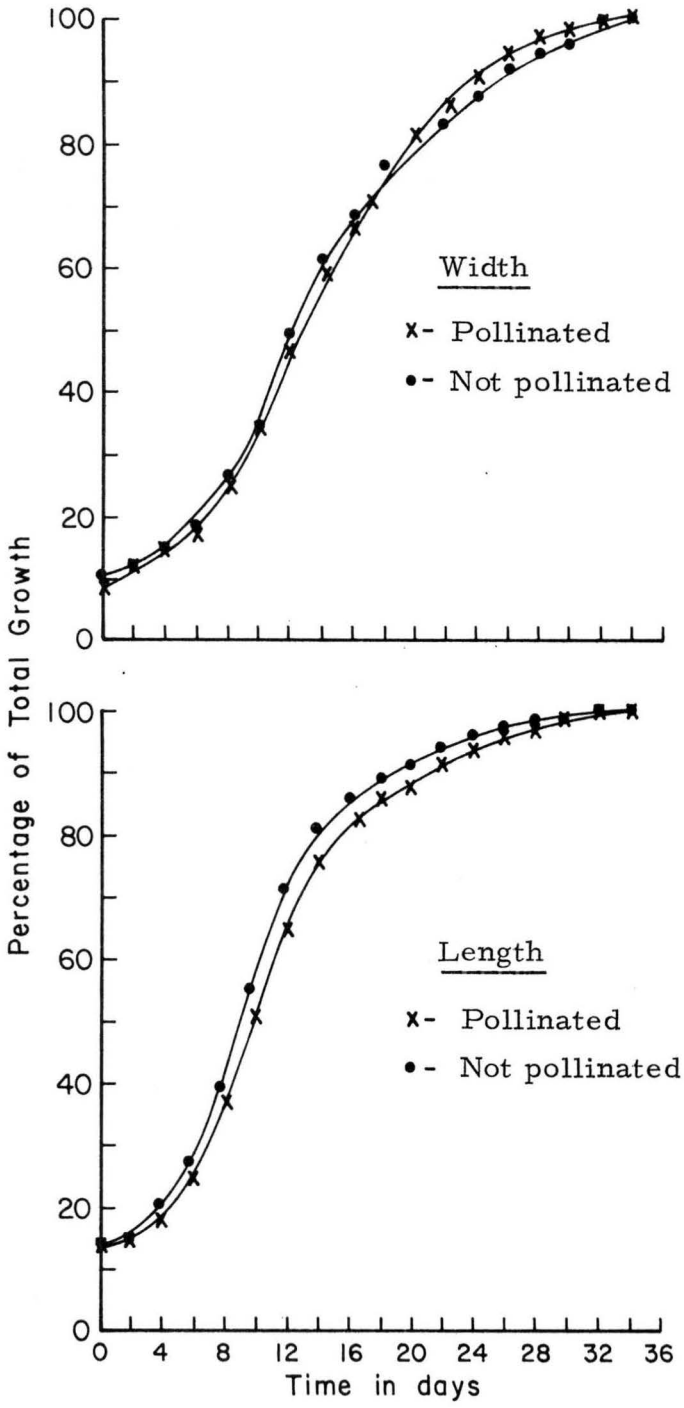


Figure 4. Sigmoid growth curves in percentage for Rocket pollinated and not pollinated fruits from flowering to maturity. Upper: fruit width; lower: fruit length.

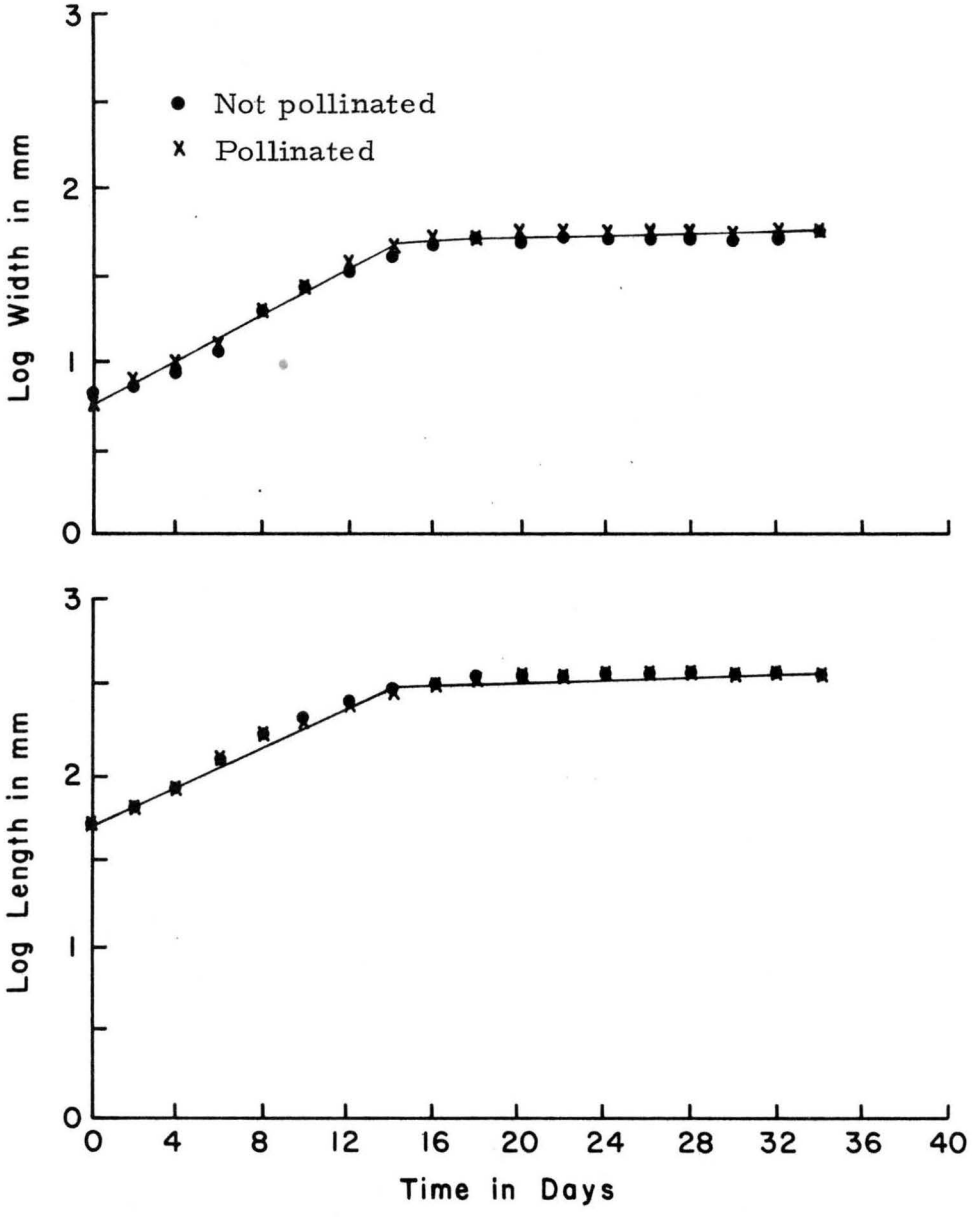


Figure 5. Growth of pollinated and not pollinated fruits of Toska 70. Log of fruit length and width plotted against time in days.

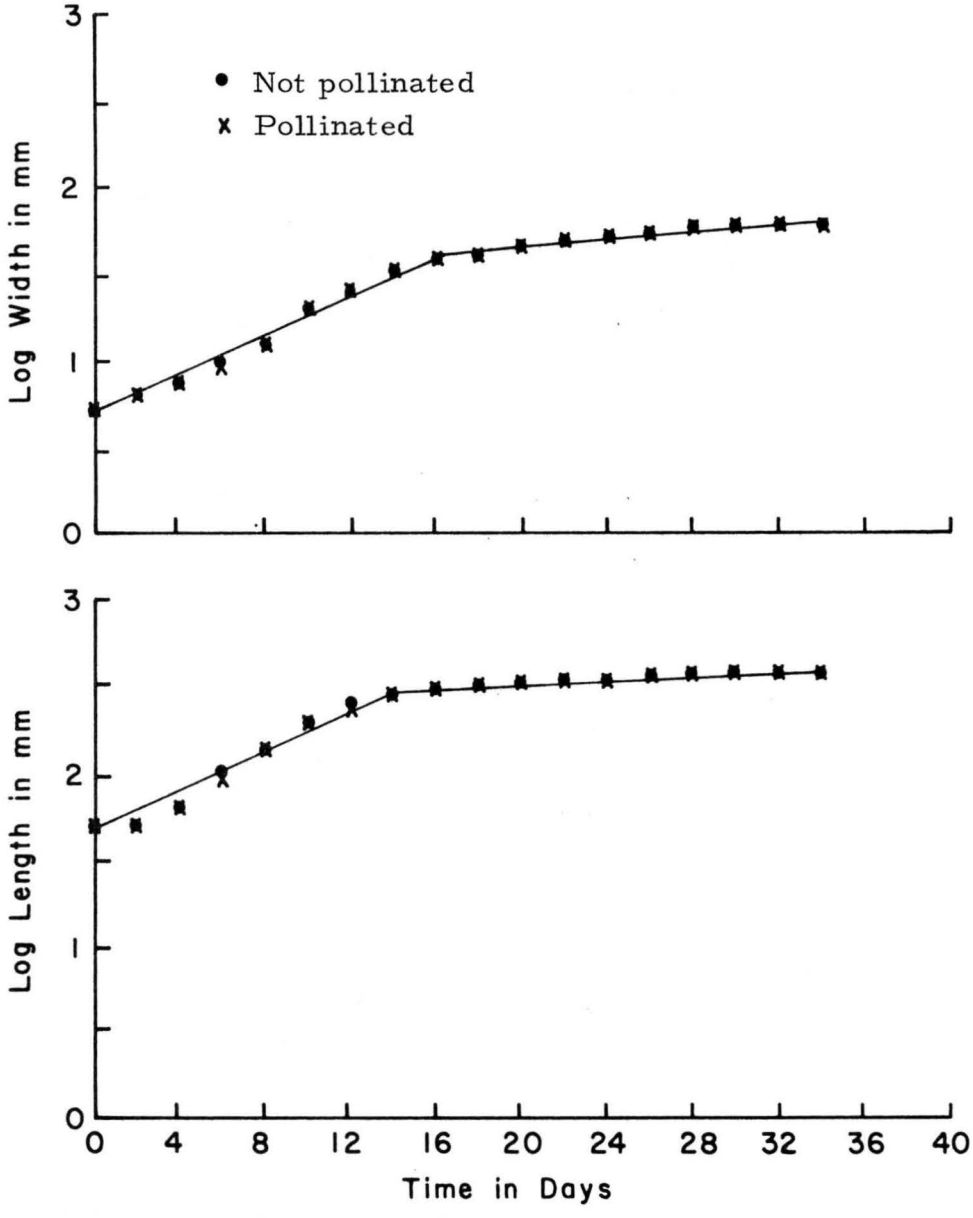


Figure 6. Growth of pollinated and not pollinated fruits of Rocket. Log of fruit length and width plotted against time in days.

of decreasing rate until fruit growth ceases when the fruit is fully mature. The rate and duration of growth are essentially the same in both pollinated and not pollinated fruits.

The genetically parthenocarpic Toska 70 and Rocket, tended to produce a larger fruit fresh weight and dry weight when not pollinated, but the t-test showed the differences to be non-significant (Table 2).

These results disagree somewhat with those reported by Denna (3). No significant differences were reported between pollinated and not pollinated fruits of Toska 70 in terms of fresh weight, but significant differences were found in the dry weight. However, Rocket and 10 other parthenocarpic cultivars produced significantly less fruit fresh weight when pollinated than without pollination. However, Denna removed the seeds from pollinated fruit and in the present studies the seeds were not removed. When the fruit and seed dry weight are combined for the pollinated Toska fruit, Denna's results agree with those reported here.

Parthenocarpy would not be expected to increase fruit fresh and dry weight of immature fruits since seed production would not have progressed to the point to retard fruit development.

The stimulatory effects of seed development on fruit development is commonly observed in fruit in which only a portion of the ovules have been fertilized. The fruit tissue adjacent to the seeds enlarges more than the rest of the fruit tissue (Figure 7). This may

Table 2. Average fresh and dry weight of mature fruit of Toska 70 and Rocket.

Variety	Fruit Condition	Fresh wt. g.		Dry wt. g.	
Toska 70	Seedless	1202.50	NS	30.60	NS
	Seeded	1116.67		26.12	
Rocket	Seedless	1133.13	NS	29.89	NS
	Seeded	1030.00		25.90	

NS = Nonsignificant.

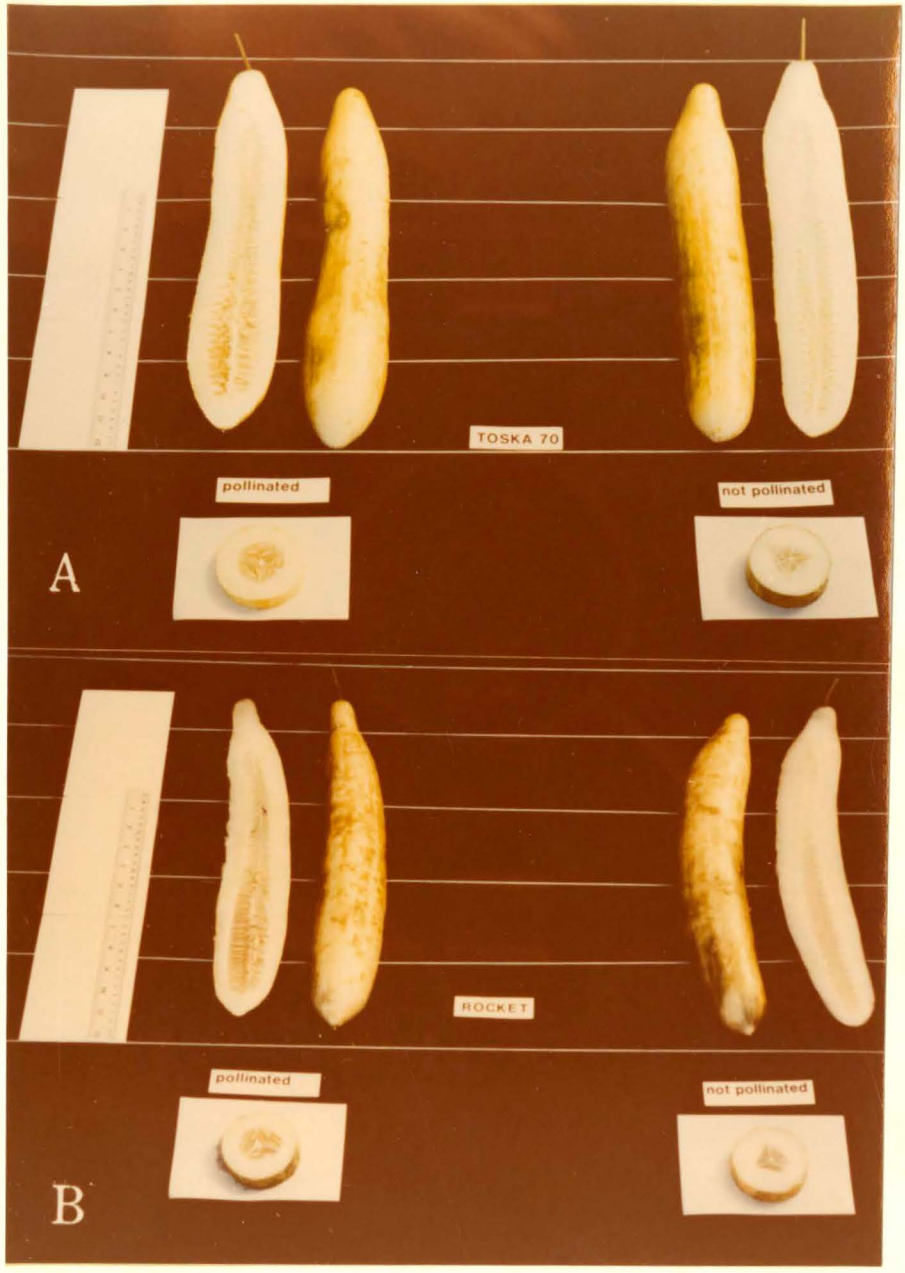


Figure 7. A. Left: Parthenocarpic Toska 70 pollinated (seeded) fruit, Right: Parthenocarpic Toska 70 not pollinated (seedless) fruit.

B. Left: Parthenocarpic Rocket pollinated (seeded) fruit, Right: Parthenocarpic Rocket not pollinated (seedless) fruit.

Note the fruit tissue adjacent to the seeds enlarges more than the rest of the fruit tissue.

result from hormones produced by the developing seeds which only effect neighboring fruit tissues.

Experiment II

Growth Differences Between Genetically Short- and Long-Fruited Lines and Varieties:

Fruit Growth in General. -- The fruit shapes of Japanese long (long-fruited), Marketmore (medium-fruited) and PI 271328 (short-fruited) are shown in Figure 8. The data for the increase in length and width of these varieties from flowering to maturity are shown in Table 3; when the data are plotted against time, typical sigmoid curves are obtained (Figure 9). The change in the percentage of total growth with time is shown in Figure 10. The following is apparent from these growth curves: growth begins slowly (lag phase), then increases rapidly (linear phase), then slows down and finally ceases at maturity.

When the log of the length and width are plotted against time, growth follows a straight line initially, but later declines (Figure 11). From this plot, a better comparison of fruit growth of Japanese long, Marketmore, and PI 271328 is possible. In each fruit type, the growth consists of two phases: an initial phase having a constant exponential rate (straight line), followed by a final phase of decreasing rate until fruit growth ceases. Furthermore, long and short fruits which are here compared, grow at essentially the same rates, but for

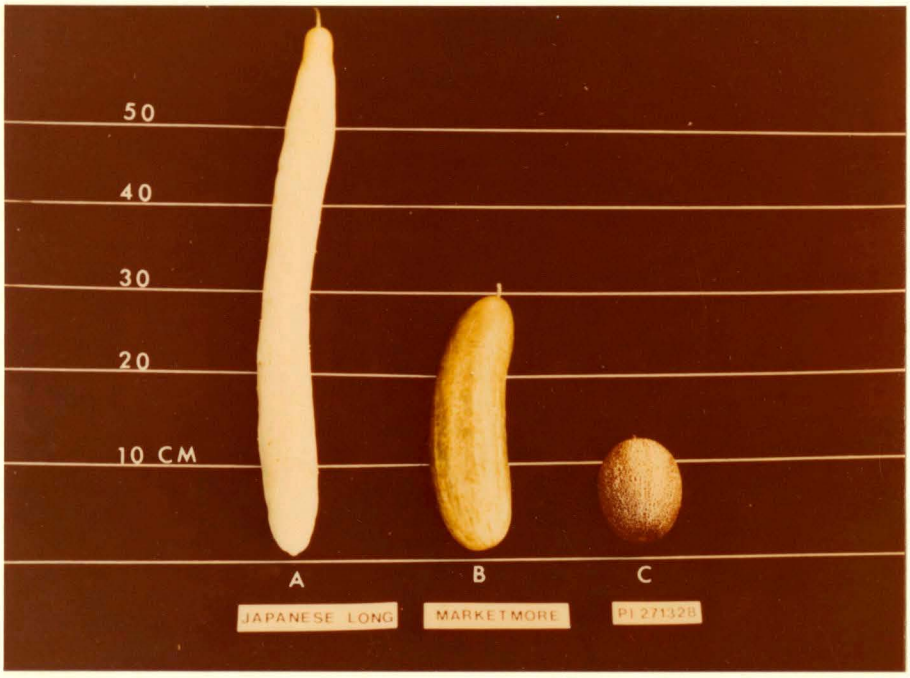


Figure 8. Cucumber varieties and line used in the study of growth differences between genetically short- and long-fruited cucumbers.

Table 3. Growth and percentage of total growth of Japanese long, Marketmore and PI 271328 fruits, from flowering to maturity.

Variety	Time Days	Length cm.	Percent	Width cm.	Percent
Japanese	0	3.7	8	0.4	9
	2	4.8	10	0.5	11
	4	5.8	13	0.6	13
	6	8.6	19	0.7	15
	8	11.0	24	0.9	20
	10	15.0	33	1.2	26
	12	21.0	46	1.6	35
	14	26.4	58	2.0	43
	16	30.8	67	2.5	54
	18	34.2	75	3	65
	20	37.5	82	3.3	72
	22	40.0	87	3.8	83
	24	42.3	92	4.0	90
	26	44.3	97	4.2	91
	28	44.8	98	4.4	96
	30	45.4	99	4.5	98
	32	45.8	100	4.6	100
	34	45.8	100	4.6	100
Marketmore	0	2.5	10	0.6	8
	2	3.2	12	0.8	11
	4	4.6	18	1.1	15
	6	7.4	29	1.8	25
	8	11.0	43	2.6	36
	10	14.7	57	3.5	47
	12	17.0	66	4.3	60
	14	19.6	76	5.0	69
	16	21.0	82	5.5	76
	18	22.3	87	5.9	82
	20	23.3	91	6.3	87
	22	23.7	92	6.5	90
	24	24.2	94	6.8	94
	26	24.9	97	6.9	96
	28	25.3	98	7.1	99
	30	25.6	99	7.1	99
	32	25.7	100	7.2	100
	34	25.7	100	7.2	100

Table 3. Continued.

Variety	Time Days	Length cm.	Percent	Width cm.	Percent
PI 271328	0	1.1	13	0.7	11
	2	1.5	18	0.8	13
	4	2.0	24	1.0	16
	6	3.0	37	1.4	23
	8	3.5	43	1.8	29
	10	4.0	49	2.5	41
	12	5.8	71	3.3	54
	14	6.6	80	4.0	66
	16	7.1	87	4.6	75
	18	7.5	91	5.1	84
	20	7.8	95	5.5	90
	22	7.9	96	5.7	93
	24	8.1	99	5.9	97
	26	8.1	99	6	98
	28	8.2	100	6.1	100
	30	8.2	100	6.1	100

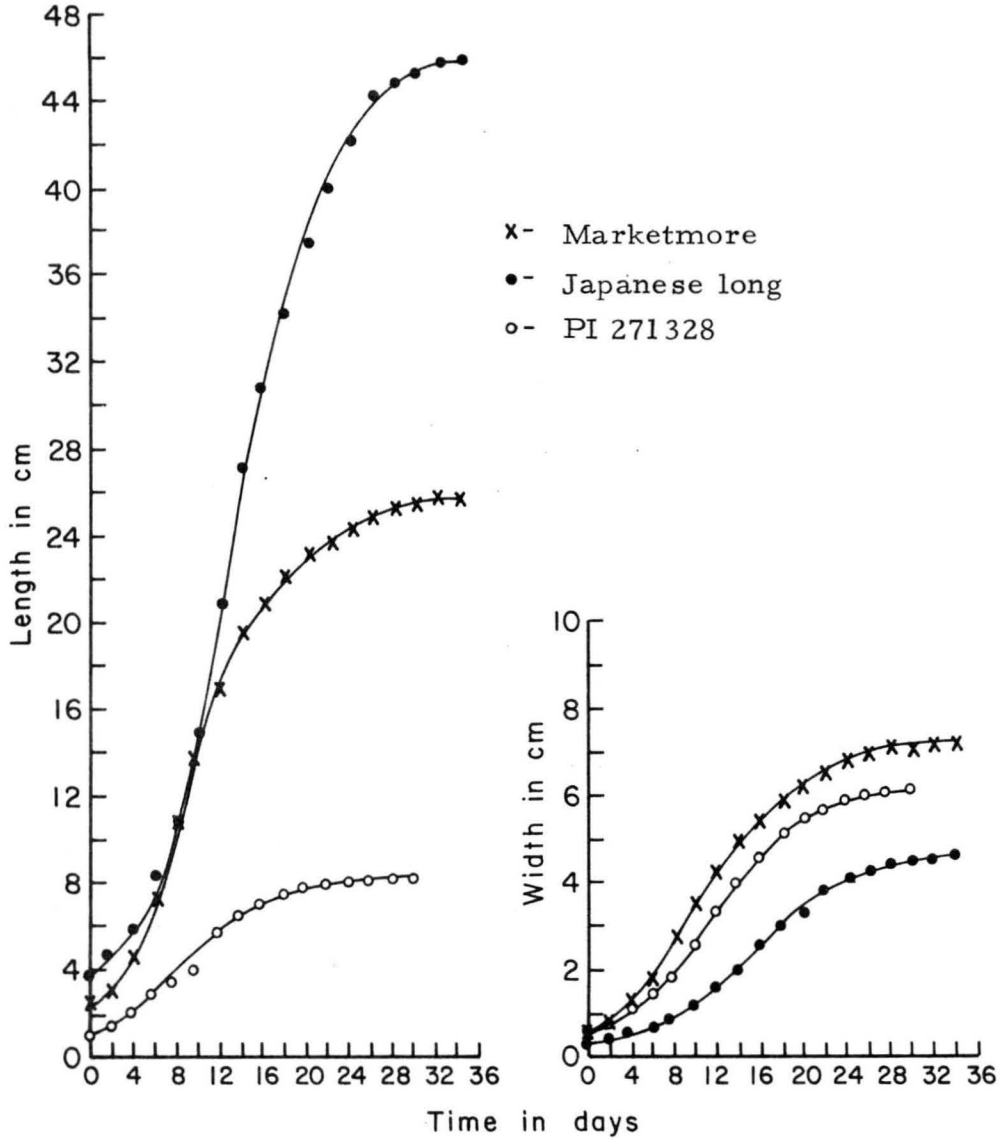


Figure 9. Sigmoid growth curves of Japanese long, Marketmore, and PI 271328 fruits from flowering to maturity. Left: fruit length; right: fruit width.

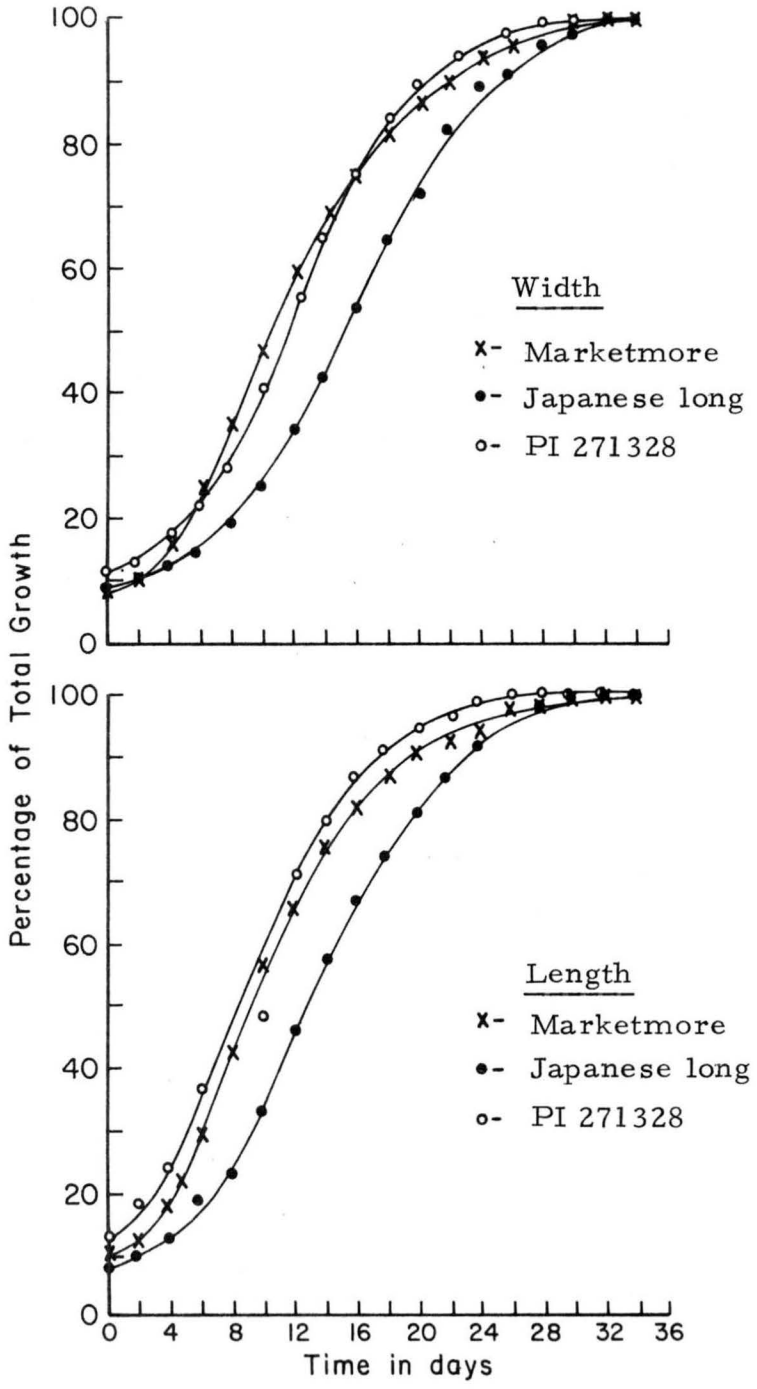


Figure 10. Sigmoid growth curves in percentage for Japanese long, Marketmore, and PI 271328 fruits from flowering to maturity. Upper: fruit width; lower: fruit length.

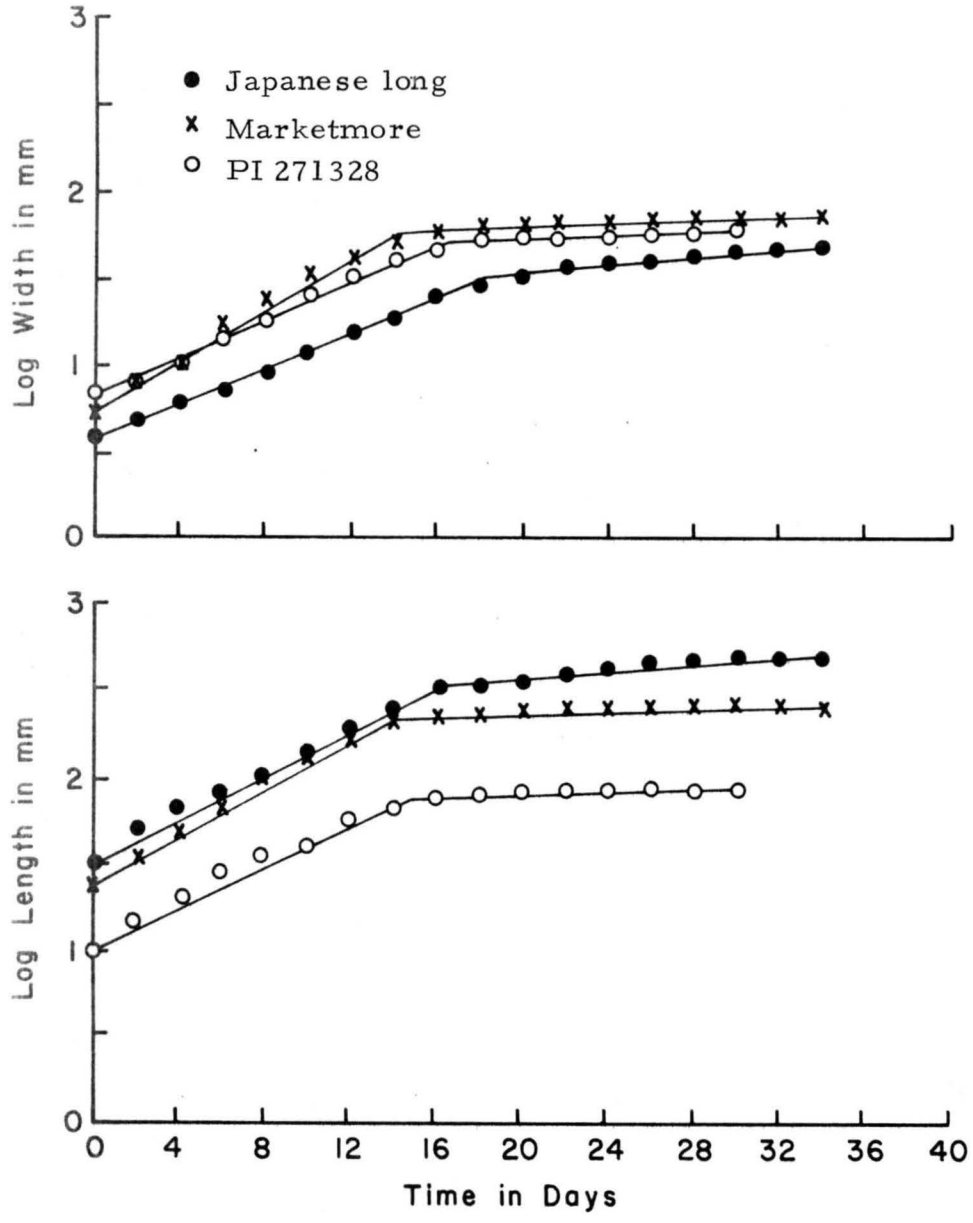


Figure 11. Fruit growth of Japanese long, Marketmore and PI 271328. Log of fruit length and width plotted against time in days.

different durations. For example, the fruit growth of Japanese long (long-fruited) is accomplished in 34 days, but in PI 271328 (short-fruited), it required 30 days. These findings are similar to those reported by Sinnott (25). He suggested that genetic factors for fruit size may operate by controlling the production or destruction of physiologically active substances like the vitamins and hormones necessary for fruit growth.

Quantitative analyses of the growth hormone concentrations in long- and short-fruited varieties at different stages of development may explain the differences in the growth duration and ultimate size.

Correlation Study. --Overall correlation between ovary length at blooming and mature fruit length for Japanese long "long-fruited," Marketmore "medium-fruited," and PI 271328 "short-fruited" was 0.97.

This result could be of practical importance with certain cultivars in predicting mature fruit length from ovary length at flowering. In other words, the long-fruited types will have longer ovaries.

Cytological Techniques. --

A. Mitotic Studies: Figure 12 shows photomicrographs of mitotic division in three ovary maturities in cucumber: a) very young ovary, b) young ovary, and c) ovary of flower on the day it opened. No cell division was observed in ovaries after pollination. This suggests that cell division ceases at or shortly after anthesis (flower

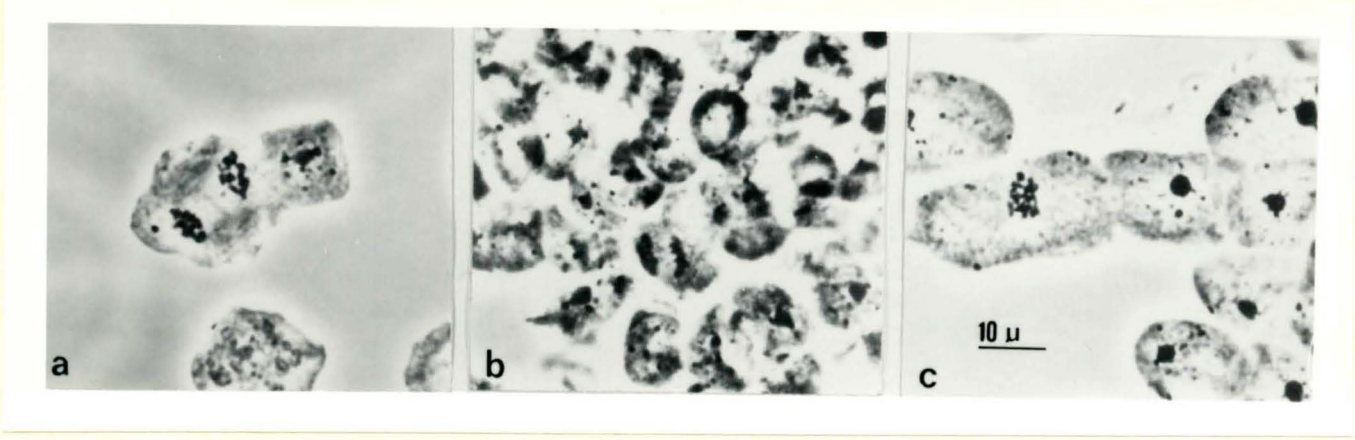


Figure 12. Photomicrographs of mitosis in three stages of cucumber ovary growth: a) anaphase in very young ovary; b) anaphase in young ovary; c) metaphase in ovary on the day flower opened.

opening) and the subsequent growth of the fruit following pollination is primarily due to an increase in cell size rather than in cell number. These results agree with those of Houghtaling (9) on tomatoes.

B. Cell Size and Cell Number Studies:

The data for cell volume and cell number of Japanese long (long-fruited), Marketmore (medium-fruited) and PI 271328 (short-fruited) cucumber are shown in Table 4.

The analysis of variance for cell volume (Table 5) showed highly significant differences between varieties, between regions and a highly significant interaction between varieties and regions.

The analysis of variance for cell number (Table 6) indicated highly significant differences between varieties, regions and their interaction. An inverse relationship existed in all varieties between cell volume and cell number (Table 4).

From Table 4 and from Figures 13 and 14, it is clear that the cell volume increases toward the inner part of the fruit in all types. Crane (2) reported that seeds are rich in auxins, gibberellins and cytokinins. Wareing and Phillips (29) suggested that auxins and gibberellins move out from the young developing seeds to the other parts of the fruit.

The highly significant differences in the cell volume between varieties may be related to differences in growth hormone concentrations. Long-fruited type may have larger cells due to a highest

Table 4. Average fruit length and width (in cm), region volume in cubic cm), average cell volume (in cubic microns) and cell number (in millions of cells), in mature fruits of three varieties of cucumber.

Variety	Average Fruit Length (cm)	Average Fruit Width (cm)		Region Volume (cu cm)	Average Cell Volume (cu μ)	Cell Number (10^6)
Japanese	45.8	4.6	I	13.34	36,608	364
			II	19.50	349,779	55
			III	19.37	1,025,709	18
Marketmore	25.7	7.2	I	11.70	5,809	2014
			II	17.42	93,224	186
			III	17.16	580,171	29
PI 271328	8.2	6.1	I	2.08	1,860	1118
			II	3.12	37,307	83
			III	3.06	338,473	9

Table 5. Analysis of variance for cell volume data from Experiment 2.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Main plots:				
Varieties (V)	2	3.8299	1.9150	19150**
Error 1	6	0.0005	0.0001	
Sub-plots:				
Regions (R)	2	16.5532	8.2766	41383**
R x V	4	0.5247	0.1312	656**
Error 2	12	0.0025	0.0002	
Total	26	20.9108		

**Highly significant.

Table 6. Analysis of variance for cell number data from Experiment 2.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Main plots:				
Varieties (V)	2	552.54	276.27	9209.00**
Error 1	6	0.19	0.03	
Sub-plots:				
Regions (R)	2	3989.47	1994.74	28496.29**
R x V	4	520.82	130.21	1860.14**
Error 2	12	0.78	0.07	
Total	26	5063.80		

**Highly significant.

Figure 13. Transvase sections of mature fruits in cucumber showing the epidermis and the three successive layers used in the cell size and cell number study. a) Japanese long; b) Marketmore; c) PI 271328.

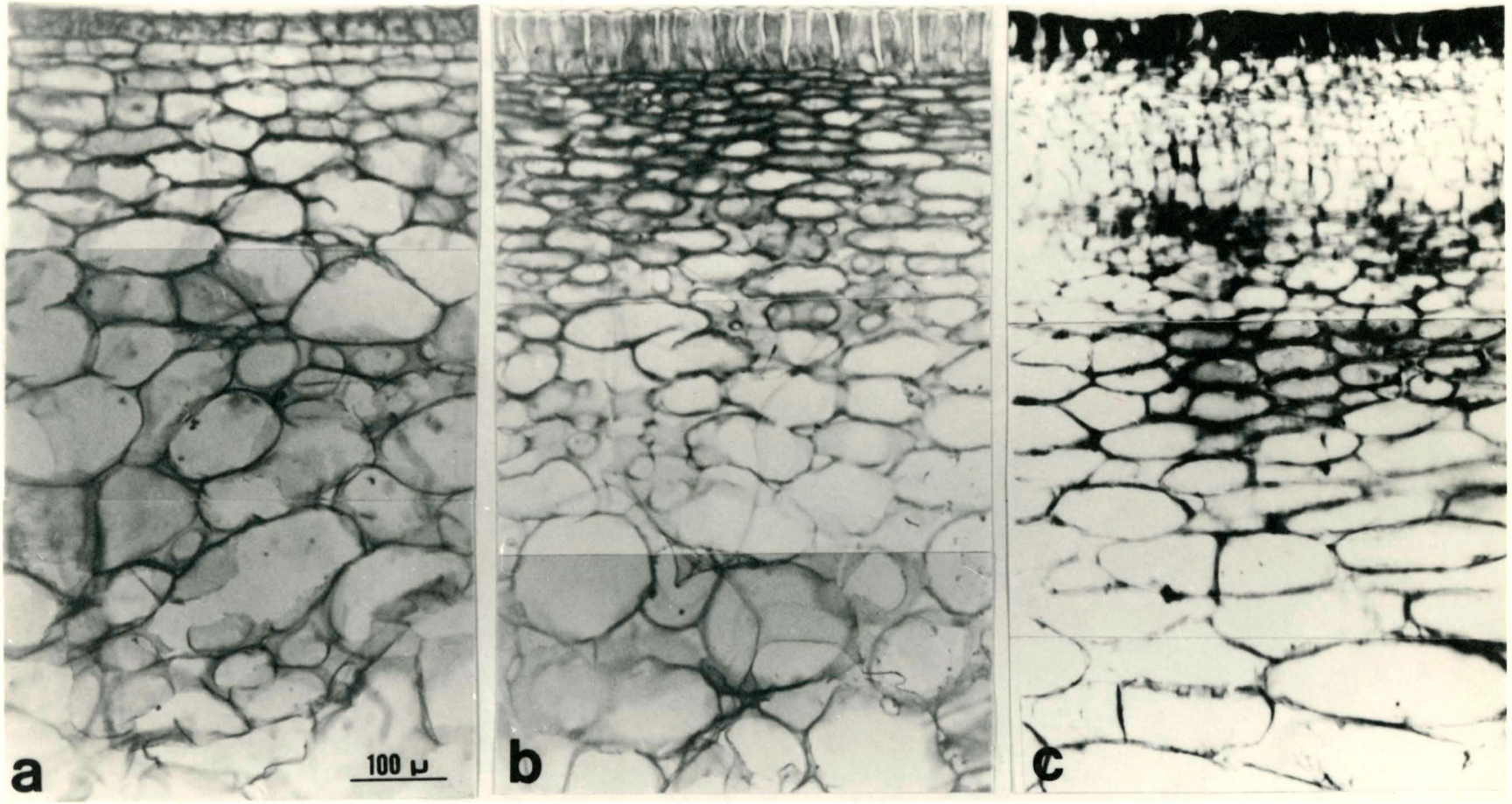
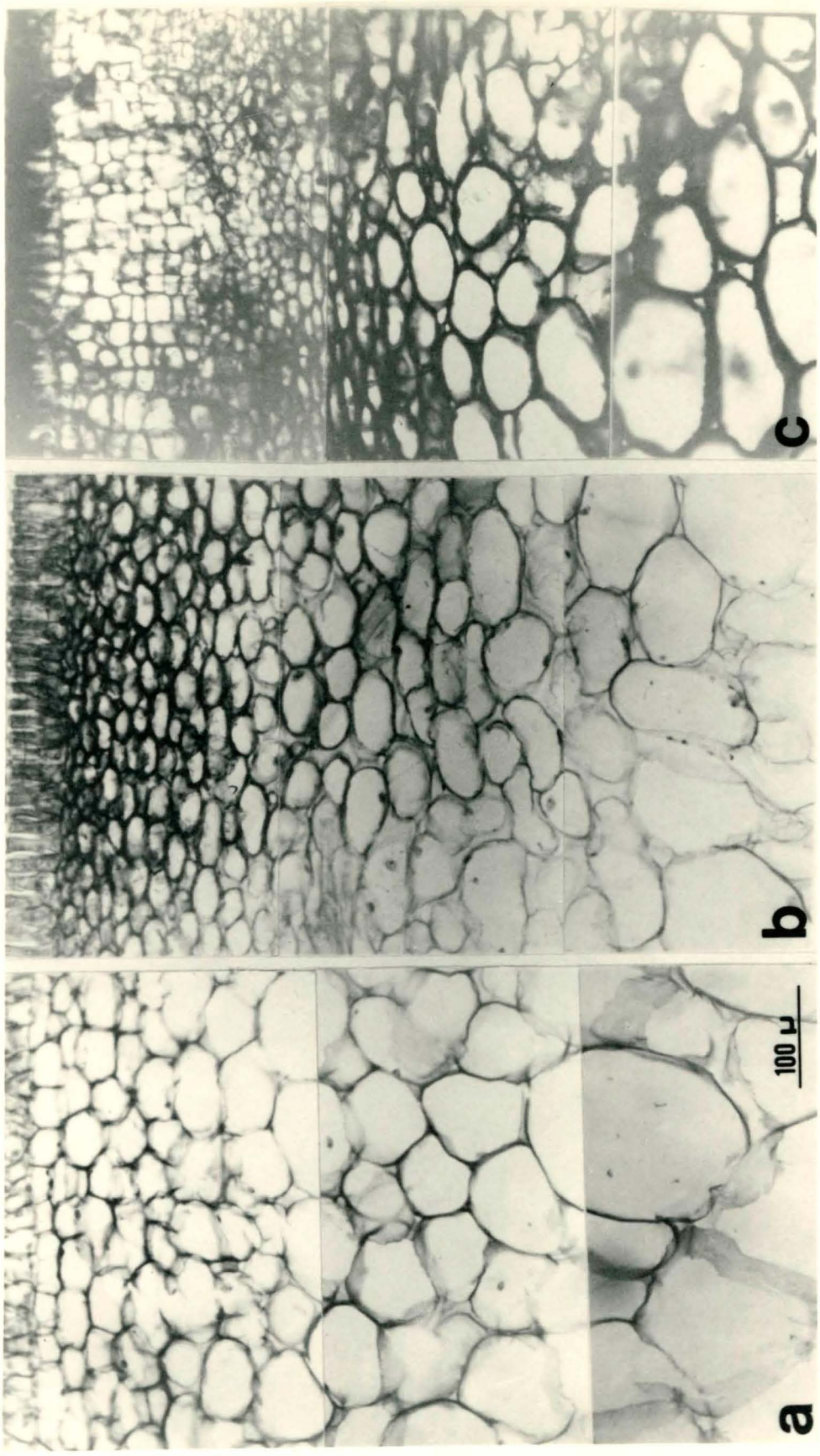

a
100 µ
b
c

Figure 14. Longitudinal sections of mature fruits in cucumber showing the epidermis and the three successive layers used in the cell size and cell number study. a) Japanese long; b) Marketmore; c) PI 271 328.


a
b
c
100 µ

concentration of growth hormone. The highly significant differences between regions may also be attributed to this factor.

The highly significant differences in the cell number between the varieties resulted from Marketmore (medium-fruited) having more cells in the three regions studied than either the Japanese long (long-fruited) or PI 271328 (short-fruited). Furthermore, the short-fruited line had more cells in regions I and II than the long-fruited variety, but less cells in region III. Since the three regions studied represent a very small part of the mesocarp layer, and due to cell size increasing toward the inner regions, most likely the longer fruit has more cells than the short one. Only a small part of the outer part of the mesocarp layer was studied since the thin wall of the inner mesocarp cells resulted in a collapse of these cells.

The relation of cell size and cell number to fruit size is complex and is the result of the entire developmental process. It cannot be solved merely by comparing the sizes of mature fruits. A careful descriptive analysis of the entire course of development would help to understand the relations which are found at maturity and to identify the various processes which are involved in growth and differentiation.

CHAPTER V

SUMMARY

A. Growth Differences Between Genetically Parthenocarpic Seeded (Pollinated) and Seedless (Not Pollinated) Fruits

Two genetically gynoecious, parthenocarpic European greenhouse cultivars, Toska 70 and Rocket, were used in Experiment I. The flowers of the pollinated and non-pollinated treatments were tagged on the day of opening. The width and length of each fruit was measured every other day beginning when the female flower opened and continuing until fruit growth ceased.

Fresh weight and dry weight of each tagged fruit were taken after harvesting.

Growth in all cases was sigmoidal consisting of an initial phase of slow growth (lag phase), then a period of rapid growth (linear phase), and finally, a slowing down until growth ceases at maturity.

The rate and duration of growth were essentially the same in both varieties and whether or not pollinated.

The genetically parthenocarpic Toska 70 and Rocket, produced a larger fruit fresh and dry weight when not pollinated, but the t-test showed the differences to be non-significant.

B. Growth Differences Between Genetically Short- and Long-Fruited Lines and Varieties

The width and length of each tagged fruit of Japanese long (long-fruited), Marketmore (medium-fruited), and PI 271328 (short-fruited) were taken every other day beginning when the female flower opened and continuing until fruit growth ceased.

Growth in all cases was again sigmoidal. The long- and short-fruited types grow at essentially the same rate, but for different durations.

Overall correlation between ovary length at blooming and mature fruit length for long-, medium- and short-fruited cucumber was 0.97. This suggests that long-fruited types will have longer ovaries.

The mitotic status was determined of four ovary maturities in cucumber: a) very young ovary, b) young ovary, c) ovary when flower opened, and d) after pollination. No cell division occurred in ovaries after pollination. This suggests that cell division ceases at or shortly after anthesis (flower opening) and the subsequent fruit growth is due to cell enlargement rather than cell number.

The analysis of variance for cell size and cell number in mature fruits of long-, medium- and short-fruited varieties showed highly significant differences between varieties, between regions and their interaction.

An inverse relationship existed in all varieties between cell volume and cell number. Cell volume increased toward the inner part of the fruit in all types.

Differences in fruit size were usually due to differences in both cell number and cell size.

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