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CONTENTS

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WATERMELON BREEDING[1]

D. R. PORTER[2]

INTRODUCTION

Although the watermelon, *Citrullus vulgaris* Schrad., has been cultivated in America since 1629[(9)] and in Africa for over 4,000 years,[(7)] relatively little attention has been given to the effects of inbreeding, to environmental factors affecting fruit setting, or to measured varietal improvement through modern breeding methods. The effects of inbreeding assume economic importance because many watermelon varieties, normally subject to extensive cross-pollination, are apparently heterozygous as to many characters, particularly those affecting plant vigor; size, shape, and color of fruit; color and texture of flesh; sugar content; and certain seed characters.

Doubtless the most important improvement needed in watermelons is the development of strains resistant to the wilt disease, caused by *Fusarium niveum* E. F. S. Wilt is now a factor limiting production in the Sacramento, San Fernando, and San Joaquin valleys of California and in many other states. As the fungus is well established in the southern states, growers have some difficulty in locating disease-free soil. A single crop of watermelons often contaminates the soil to the extent that all subsequent crops may be seriously infected. Eventually, therefore, all the watermelon districts, each demanding a particular type of fruit, will probably need wilt-resistant strains.

As inbreeding must continue for several generations in order to establish homozygous wilt-resistant strains, workers evidently must (a) measure the effect of such inbreeding, (b) establish the mode of inheritance, (c) develop pollination technique, and (d) determine the occurrence of self-sterility. In the light of these needs, the work reported

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herein was initiated in 1929 and briefly reported in 1930.[14] Previous experience with the wilt disease in Iowa, already described,[15] emphasized the necessity of these investigations. The studies herein reported were conducted mainly with the Klondike variety.

HISTORICAL

The effects of inbreeding have been more thoroughly investigated in the Cucurbitaceae than in any other family of vegetable crops. The earlier workers, Drude,[4] Lotsy,[10] and Sinnot and Durham,[20, 21] dealing with certain varieties of *Cucurbita pepo* noted the extreme difficulty of effecting self-fertilization and agreed that sterility and loss of vigor combined to hinder the establishment of pure lines. Bushnell,[2] however, working with Hubbard squash (*C. maxima*) at the Minnesota station, concluded that inbreeding tended to isolate strains of high quality and marked uniformity, yielding only slightly less than the commercial check lots, and that F_1 hybrids between the inbred lines showed only slightly more vigor than the inbred lines, or about the same amount as the commercial check lots. Rosa,[18] working with *Cucumis melo* in California, showed that the second generation of inbred lines of the Salmon Tint cantaloupe might yield more or less than the parent variety; that lines differing in fruit shape from the parent variety could be isolated; and that there were slight differences in yield of seed, average weight per seed, and the development of fruit grooves and ribs. The report of Cummings and Jenkins[3] from the Vermont station indicated that in *Cucurbita maxima* continuous self-pollination did not influence seed viability nor induce degeneration of the species. Haber's[6] experience with *Cucurbita pepo* at the Iowa station showed the possibility of inbreeding the Table Queen (Des Moines) pumpkin and, at the same time, isolating strains that produce fruits of uniform size, shape, and quality. With the exception of preliminary studies made by the writer[14] and a brief report by Rosa,[16] breeding work with the watermelon has been limited to the development of resistant strains by Orton[11, 12, 13] and by Porter and Melhus.[15] Orton, although not attempting to cross pure lines, did report that extremely vigorous F_1 hybrids resulted from crosses of the edible variety Eden with the nonedible "citron." By continued selection within hybrid material, he isolated and named the wilt-resistant variety Conquerer. In the writer's experience at the Iowa station, neither self-sterility nor apparent loss of vigor was encountered during three generations of inbreeding in the Kleckley Sweet watermelon.

Although, in general, neither consistent loss of vigor nor appreciable decrease in yield has appeared during inbreeding in the family Cucurbitaceae, just the reverse is true of *Zea mays,* likewise chiefly cross-fertilized. As shown by the work of East,[5] Shull,[22] and others on maize, marked loss of vigor results from inbreeding the progeny of individual plants for three or four generations. From the fifth to the seventh generations, apparently, the inbred lines approach homozygosity for the factors governing yield.

FLOWERING HABIT AND FLORAL STRUCTURE

Most watermelon varieties produce staminate and pistillate flowers separately in the axils of the leaves. In some varieties—Angeleno, Chilean, Baby Delight (Hungarian Honey), and Winter Queen—hermaphroditic flowers are often, but not always, borne in place of pistillate. They produce an abundance of pollen, apparently indistinguishable from that produced by staminate flowers on the same plant. Rosa[16] has reported, and the writer has observed, that pistillate flowers are not fertilized if bagged before anthesis, a fact indicating the complete absence of parthenocarpy in several varieties of the species.

The ratio of pistillate or hermaphroditic to staminate flowers is not constant. Although actual counts have indicated a ratio of approximately 1 to 7 in the most important commercial varieties, female flowers are sometimes found at every third, fourth, ninth, or tenth node. They have, furthermore, been observed at adjacent nodes as well as in pairs at a single node. Though hermaphroditism might be considered desirable, as serving to increase the probability of self-pollination, no one, apparently, has attempted to introduce this characteristic into Klondike or other important commercial varieties. Obviously, not all the pistillate flowers set fruit; indeed, the average number of fruits per plant in Klondike (commercial lots) is probably less than 6 under field conditions, while many plants form 40 or more pistillate flowers during the blooming period.

Though the Klondike flower type is adapted to complete cross fertilization, the amount of natural crossing in the field has never been measured. Apparently, however, the first pistillate flowers to open, on a given plant, are more likely to be self-pollinated than those that open after the vines begin to intermingle. Pollination seems to be almost entirely the work of insects.

The number of flowers that open daily on a given plant is exceedingly variable, probably depending upon the age and vigor of the plant and upon environmental factors during the preceding day and night. Under normal growing conditions, open female flowers are usually found 12 to 18 inches from the outer extremity of the runner. If there is insuffi-

Fig. 1.—Watermelon pollination, showing three stages in the life history of the pistillate flower. Left, open pistillate flower with a wilted corolla and withered stigma 24 hours after anthesis, showing open staminate flower at a *younger* node. Middle, pistillate flower two hours after anthesis, showing dehiscing staminate flower at an *older* node. Right, pistillate flower about 24 hours before anthesis, showing staminate flower at an *older* node.

cient soil moisture, abnormally high temperature, or disease infection, flowers may open within 2 inches of this outer extremity. In such cases, however, fertilization has not been observed to follow pollination.

Under environmental and cultural conditions in the Sacramento and San Joaquin valleys of California during June, July, and August, both pistillate and staminate flowers usually open between 6 and 8 a.m. The time apparently depends upon the air temperature during the preceding night. If the night is unusually warm (60° to 70° F), many flowers are fully open by 6 a.m.; if cool, the time of flower opening is delayed. Pollen is often shed one to three hours before anthesis; and dehiscence often continues until late afternoon, when the corolla closes and the anthers begin to wither. These investigations have not definitely determined the length of time the pollen remains viable, nor the relation of temperature to rate of pollen germination and pollen tube growth. The stigmatic surface appears receptive at anthesis and generally remains sticky until the corolla closes.

Although anthesis of pistillate and staminate flowers is usually simultaneous, in the former case it is almost invariably found at the younger node on a given runner (fig. 1) and is usually accompanied by one to three open staminate flowers at nodes immediately preceding. In hermaphroditic flowers, anthesis seems to be considerably retarded. Within their closed corolla, pollen may be shed and the stigma may appear receptive 24 hours before anthesis. At this time, self-fertilization may be effected if the corolla is opened artificially and the pollen applied to the stigmatic surface. In hermaphroditic flowers at anthesis, the ovaries and stigmas are relatively larger than in purely pistillate flowers of the same variety.

POLLINATION TECHNIQUE

The technique of artificial self-pollination is essentially the same for all varieties of *Citrullus vulgaris* except the hermaphroditic; in the latter case, staminate flowers need not be bagged before anthesis, as the hermaphroditic ones produce sufficient pollen. The following description applies to varieties producing purely staminate and pistillate flowers. Within 24 hours (or less) before anthesis, pistillate and staminate flowers are selected and are covered with a small muslin bag having a draw string (figs. 2, 3, and 4). The former are always younger than the latter and are located at nodes farther from the crown of the plant. As soon as possible after anthesis, these cloth bags are removed, the staminate flower is pinched off, and pollen is applied to the stigmatic surface. A one-pound manila paper bag is then slit for about three inches down each side, folded tightly over the pollinated flower, and fastened with a clip (fig. 5). After two days, this paper bag is removed. In making crosses involving hermaphroditic flowers, one must emasculate before

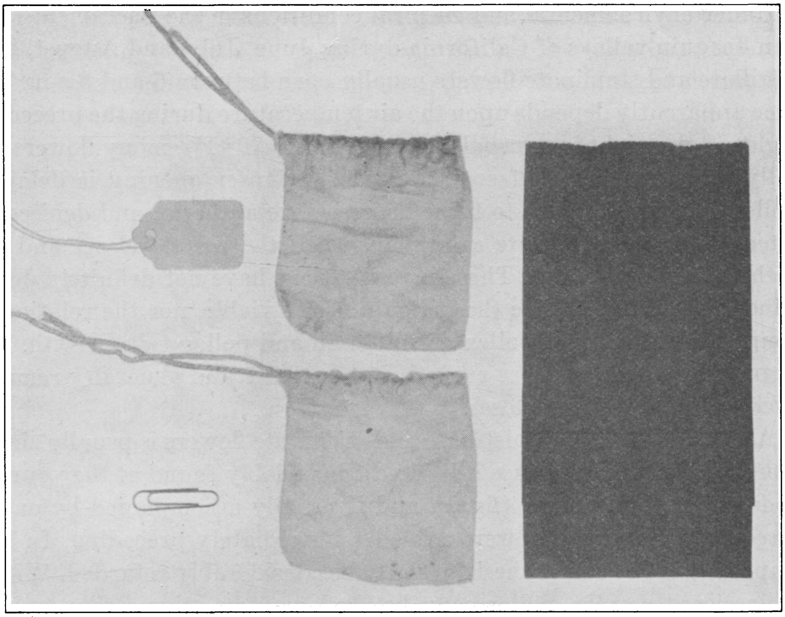

Fig. 2.—Equipment used in watermelon pollination. Two cloth bags for covering flower buds; one-pound manila paper bag for screening pistillate flowers after pollination; paper clip for holding paper bag in place to prevent insect visitation; and label for recording pollination data as explained in text.

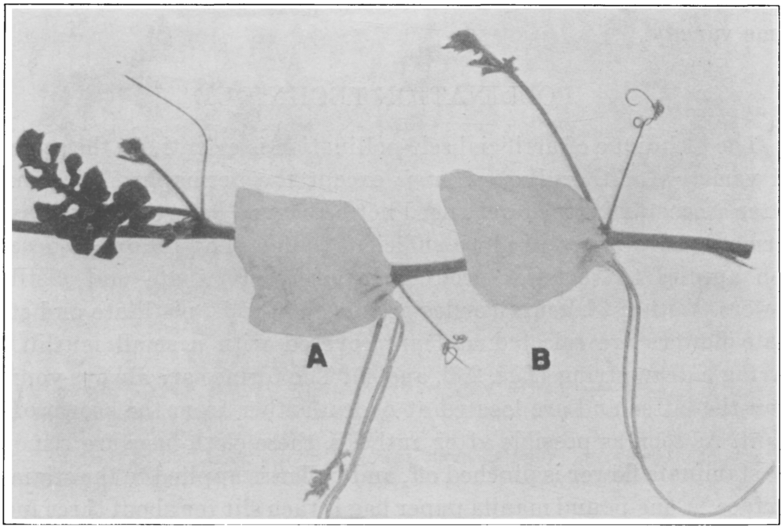

Fig. 3.—Watermelon pollination, showing cloth bags in place over pistillate flower *A* and staminate flower *B*. These bags are placed over the flower buds during the afternoon or evening immediately preceding anthesis. They are rarely entered by insects.

dehiscence as well as before anthesis. Experience has shown that if emasculation is delayed until pollen has dehisced, contamination may result.

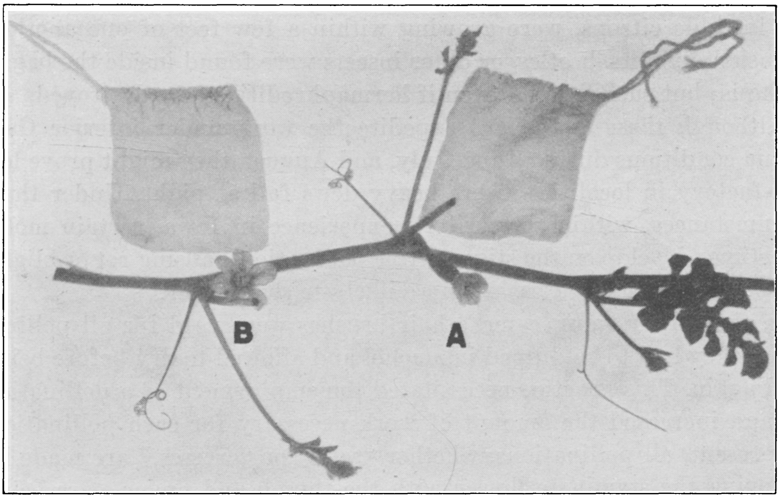

Fig. 4.—Watermelon pollination. Cloth bags removed during the morning, showing receptive pistillate flower *A*, and dehiscing staminate flower *B*. Note the relative position of these two flowers, with the staminate flower at an older node than the pistillate.

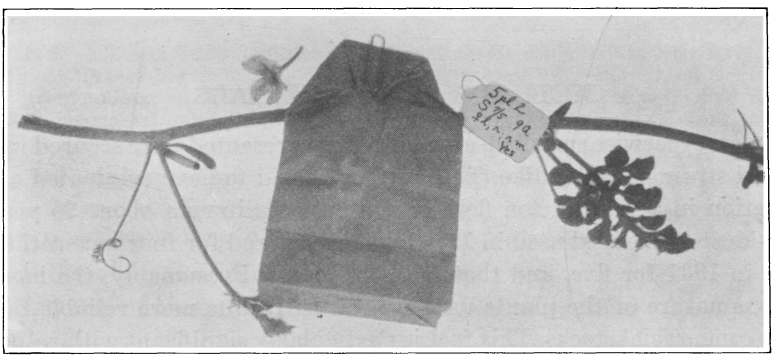

Fig. 5.—Watermelon pollination. Paper bag securely fastened over pollinated pistillate flower with pollinating data on tag, translated as follows: strain 5, plant 2; selfed July 5; 9 a.m.; female, large, receptive; runner medium; yes (meaning that fruit setting is predicted).

In the earlier work, manila paper bags were placed over both types of flowers before anthesis. Although equally effective, their use requires much more time; so, later, cloth bags were used for staminate, paper bags only for pistillate, flowers. In only a very few instances, when the cloth bags were removed, certain insects were found feeding on the pollen. Still later, cloth bags served for both types of flowers. During seven seasons' work, using cloth bags before anthesis, no evidence of contamination has appeared, even where ten or more varieties, including the inedible citrons, were growing within a few feet of one another. Occasionally ants, beetles, or other insects were found inside the bag at anthesis; but such flowers, even if hermaphroditic, were destroyed.

Although these cloth bags expedite the work under interior California conditions during June, July, and August, they might prove less satisfactory in localities where heavy dews fall at night. Under these circumstances, within the writer's experience in Iowa, certain molds sometimes develop on the stigma after pollination, causing rot or blight. Paper bags, in such cases, are more likely to shed water.

In the earlier work, camel's hair brushes were used for all pollinations; they had to be dipped in alcohol and allowed to dry before being used again. This practice necessitated the employment of a pollinating kit and increased the amount of work necessary for each pollination. At present, all pollinations, whether "selfs" or "crosses," are made by removing the staminate flower with the thumb and finger, care being taken that no part of the hand makes contact with either pollen or stigma. Because of the precautions taken, no contamination has appeared during four seasons, and the amount of labor necessary for each pollination has been materially decreased.

METHODS AND MATERIALS

Unless otherwise specified, all results here presented were secured with inbred strains of Klondike. This variety is said to have originated as a mutation in a watermelon field in southern California about 25 years ago. Most of the seed used in 1930 had been inbred for four generations, that in 1931 for five, and that in 1932 for six. Presumably, the homozygous nature of the plants used makes the results more reliable than with commercial stocks. This fact is particularly significant with respect to self-sterility, relation between weather and fruit setting, yield per plant, and pollination technique.

The distance between rows was 9 feet and that between hills in the row, 6 feet. Surface-disinfected seed was used, and the resulting plants were thinned to three, later to two, and finally to one per hill. *Diabrotica* beetles were controlled by the use of calcium arsenate mixed with lime (1:20); an occasional infestation of aphids was checked by the use of nicotine dust. With these precautions, approximately perfect stands were secured during the three years. Normal rate and frequency of irrigations were employed. Unless otherwise specified, the trials were replicated to overcome soil heterogeneity. The plants began to bloom in June (fig. 6), and the first ripe melons were harvested in late July or early August.

At harvest, or very soon after, record was made of individual fruit weight to the nearest half pound; of fruit shape, based on the equatorial and polar diameter measurements to the nearest half inch; of skin color

Fig. 6.—Watermelon pollination, showing progress made within four days after pistillate flowers began to open. When the paper bags are removed, on the second day after pollination, wooden stakes indicate the location of the pollinated flower. Periodic examination of these pollinated flowers provides the data on fruit setting.

and indentation; of rind thickness and toughness; of flesh color, texture, solidity, and relative sweetness (by taste); and of seed size and seed-coat color. From the data on individual fruits, each plant and each inbred strain was arbitrarily rated.

Throughout these investigations a simple pedigree system, initiated by the late Dr. J. T. Rosa, at this station, has been used. Each variety was designated by a number, Klondike being No. 39. Strains designated as 39–5 and 39–9 indicate that selfed melons were secured from plants 5 and 9, respectively, of variety 39. Strains 39–5–3 and 39–5–3–2 were inbred two and three generations, respectively. The original seed of variety 39 was selected by Dr. Rosa from a bulk lot produced by a seedsman at Modesto in 1923. At that time, black-seeded Klondike strains seemed to be in demand; and annual selections for this character have been made (fig. 7).

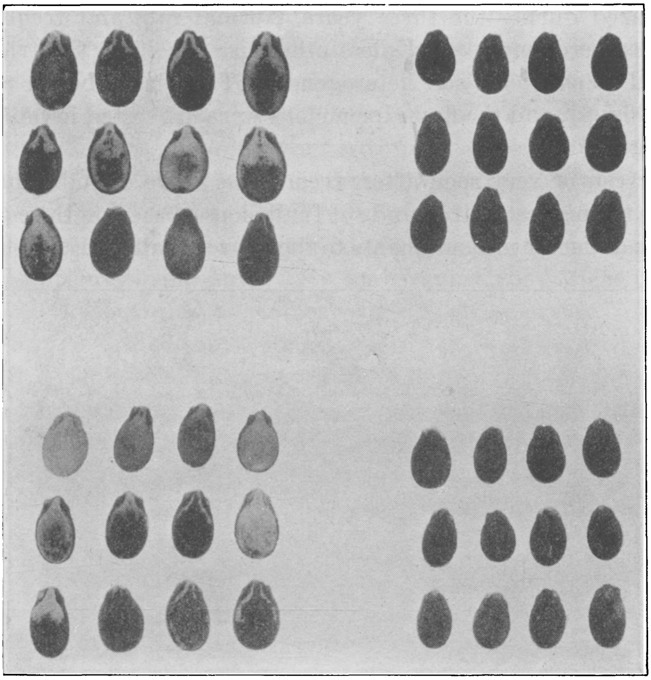

Fig. 7.—Variation in size and color of seeds produced by commercial stocks, left; by California Klondike 1, upper right; and by California Klondike 9, lower right.

EXPERIMENTAL RESULTS

In 1930, the investigations were confined to measurement of the effects of inbreeding; commercial stocks were compared with strains inbred for one, two, three, and four generations. Particular attention was directed to plant vigor, number of fruits and average yield per plant, and such fruit characters as date of maturity, size, shape, color, rind thickness, flesh color, and texture, as well as seed size and seed-coat color. In Imperial Valley, strains that produce relatively small, early-maturing fruits are much in demand, because the crop from this district begins to ripen in May with a high price per pound; growers have found it easier to sell a melon averaging 18 pounds rather than 25. In the San Gabriel, San Fernando, San Joaquin, and Sacramento valleys, however, the need for a small, early-maturing melon is less, for the crop begins to ripen much later than in Imperial Valley. Growers in these districts prefer a melon averaging 22 to 25 pounds and need more uniform stock of higher flesh quality than is now generally available.

PLANT VIGOR

In 1930, the strains indicated in table 1 were compared with respect to relative vigor of the plants. As it was physically impossible to measure accurately the leaf area or runner length, measurements of relative plant vigor consisted in observing the rate of plant growth during the season. An arbitrary classification was established as indicated in table 1. Relative vigor was recorded on June 6, July 1, and August 19; the figures were averaged for each strain with the results presented in the table. Obviously, this type of measurement is rather crude; but the data are presented to indicate that there was, to the eye at least, very little difference in relative plant vigor between the various inbred strains and the commercial stock.

TABLE 1

EFFECT OF CONTINUED INBREEDING ON PLANT VIGOR IN WATERMELONS; 1930

Pedigree	Number of generations inbred	Relative vigor*			
		June 6	July 1	August 19	Average for the season
Klondike (commercial)	....	1.7	2.4	2.8	2.32
39-5	1	2.4	2.3	2.8	2.51
39-5-3	2	2.3	2.4	3.0	2.53
39-5-3-2	3	2.1	2.3	3.0	2.47
39-5-3-2-9c	4	2.4	2.4	3.0	2.62
39-5-12a	2	2.3	2.6	3.0	2.71
39-5-12a-2	3	2.8	2.3	3.0	2.70
39-5-12a-2-1	4	2.6	2.5	2.8	2.69
39-5-3-3	3	2.2	3.1	2.5	2.45
39-5-3-3-1	4	1.8	2.3	3.0	2.48
39-9	1	2.5	2.6	3.0	2.70
39-9-3	2	2.0	2.3	3.0	2.43
39-9-3-2	3	2.5	2.2	3.0	2.55
39-9-3-2-2	4	2.5	2.5	3.0	2.66
39-9-3-4	3	2.7	2.4	3.0	2.72
39-9-3-4-9a	4	2.8	2.4	3.0	2.79

* Relative vigor of the unit 1 indicates a comparatively slow-growing vine; the unit 2 shows more thrifty growth than 1; 3 is most thrifty of all.

Similar observations and records were likewise made during 1931 and 1932, with practically identical conclusions, even though in one strain fruits matured earlier than in others. This early-maturing strain was no more vigorous; but, as will be shown later, the number of days between blooming and fruit maturity was less than with others.

Three years' observation, therefore, indicates that inbreeding of the Klondike does not tend to reduce plant vigor. On the contrary, the vines of individual inbred strains were more uniform in rate of growth than those of commercial stocks, where both extra-vigorous and relatively slow-growing vines were found. Apparently inbreeding tends to establish homozygosity of those factors responsible for rate of plant growth.

NUMBER OF FRUITS PER PLANT

Except in a few instances, indicated below, no attempt was made actually to count fruits produced by individual plants, because, when harvesting began, the vines were so intermingled that considerable injury would have resulted. The relatively large number of fruits produced and the number of replications contribute to the accuracy of the results secured. All mature fruits were included, except those infected with blossom-end rot (*Pythium*) or otherwise malformed.

Results in 1930.—Commercial Klondike produced 6.3 fruits per plant (table 2), while, with the exception of 39–5–3–2–9, the inbred strains averaged from 6.7 to 9.9. The significance of these differences cannot be statistically determined because the actual number of fruits per plant is unknown; however, with such a large total involved per strain, some of the differences are probably significant. At least, inbreeding evidently did not diminish the number of fruits produced per plant; the tendency was for an increase.

When fruits are sold at a certain price per pound, the total weight per plant is probably just as important as the total number. Late in the season, however, fruits are often sold not by the pound, but at a certain price apiece; and the number of fruits per plant then assumes considerable economic importance. An increased number of fruits per plant does not necessarily indicate an increase in the total weight per plant: decrease in individual fruit weight might tend to diminish total yield even with substantial increase in number of fruits.

Though the inbred strains, in general, tended to produce more fruits per plant than commercial stock, considerable variation appeared among the strains of the former group. Strain 39–5 produced 8.5, strain 39–5–3 produced 8.3, strain 39–5–3–2 produced 7.5, and strain 39–5–3–2–9 produced only 6.2 fruits per plant, indicating a gradual reduction with continued inbreeding. Strain 39–5–3–3 produced 8.0 while 39–5–3–3–1 produced 9.9 fruits per plant; and whereas 39–5–12 produced 6.7, strain 39–5–12–2 produced 7.9, and 39–5–12–2–1 produced 7.6 fruits per plant. With continued inbreeding in the 39–9 strain, the number of fruits per plant varied only slightly. Apparently, therefore, the average number per plant after continued inbreeding, may be extremely variable.

TABLE 2

YIELD AND TYPE OF FRUITS PRODUCED BY INBRED KLONDIKE STRAINS COMPARED WITH COMMERCIAL KLONDIKE; 1930

Pedigree	Number of generations inbred	Number of fruits produced	Average number of fruits per plant	Yield in pounds		Weight per fruit in pounds		Shape index	
				Per plant	Difference	Mean	Difference	Mean	Difference
Klondike (commercial)	0	189	6.3	121.8	....	19.6±0.25	....	645±5.9	....
39-5	1	236	8.5	138.1	+16.3	16.8±0.17	−2.8±0.302	851±5.9	+206± 8.344
39-5-3	2	215	8.3	130.9	+ 9.1	16.2±0.16	−3.4±0.297	818±6.5	+173± 8.772
39-5-3-2	3	150	7.5	142.6	+20.8	19.3±0.27	−0.3±0.369	670±8.0	+ 25± 9.941
39-5-3-2-9	4	155	6.2	125.3	+ 3.5	19.9±0.27	+0.3±0.369	627±3.8	− 18± 7.799
39-5-12	2	188	6.7	106.7	−15.1	16.2±0.17	−3.4±0.302	946±6.4	+301± 8.653
39-5-12-2	3	119	7.9	145.1	+23.3	19.4±0.27	−0.2±0.369	1,034±3.9	+389± 7.003
39-5-12-2-1	4	210	7.6	120.9	− 0.9	16.3±0.18	−3.3±0.308	774±8.9	+129±10.71
39-5-3-3	3	76	8.0	110.7	−11.1	12.4±0.18	−7.2±0.308	583±6.1	− 62± 8.487
39-5-3-3-1	4	249	9.9	131.4	+ 9.6	13.6±0.11	−6.0±0.273	604±4.2	− 41± 7.242
39-9	1	225	7.1	125.6	+ 3.8	18.8±0.22	−0.8±0.333	751±6.4	+106± 8.653
39-9-3-2	3	197	7.0	127.2	+ 5.4	20.3±0.21	+0.7±0.326	569±3.6	− 76± 8.232
39-9-3-2-2	4	196	7.3	128.6	+ 6.8	18.8±0.18	−0.8±0.308	548±3.8	− 97± 6.989
39-9-3-4	3	221	7.4	139.9	+18.1	19.2±0.21	−0.4±0.326	608±3.2	− 37± 6.712
39-9-3-4-9	4	209	7.8	145.9	+24.1	19.3±0.22	−0.3±0.333	614±3.2	− 31± 6.712

TABLE 3

YIELD AND TYPE OF FRUITS PRODUCED BY INBRED KLONDIKE STRAINS COMPARED WITH COMMERCIAL KLONDIKE; 1931

Pedigree	Average number of fruits per plant	Yield in pounds		Weight per fruit in pounds		Fruit shape index	
		Per plant	Difference	Mean	Difference	Mean	Difference
Klondike (commercial)	4.1	72.9	....	17.8±0.41	....	639± 6.3	....
39-5-3-2-1-1	4.6	79.1	+ 6.2	17.2±0.32	−0.6±0.52	593± 8.4	−46±10.5
39-5-3-2-1-2	4.6	84.6	+11.7	18.4±0.47	+0.6±0.62	607± 8.1	−32±10.2
39-5-3-2-5-1	4.6	83.2	+10.3	18.1±0.07	+0.3±0.41	602± 7.1	−37± 9.5
39-5-3-2-5-2	4.6	83.7	+10.8	18.2±0.38	+0.4±0.56	589±10.7	−50±12.4
39-5-3-2-5-3	3.2	63.1	− 9.8	19.1±0.62	+1.3±0 74	590±10.6	−49±12.3
39-5-3-2-6-1	4.6	89.2	+16.3	19.4±0.59	+1.6±0.72	610± 6.5	−29± 9.05
39-5-3-2-6-2	3.6	61.9	−11.0	17.2±0.59	−0.6±0.72	598±10.6	−41± 9.1
39-5-3-4-2-1	4.6	79.1	+ 6.2	17.2±0.37	−0.6±0.54	588± 8.0	−51±10.2
39-5-4-3-5-1	4.6	79.6	+ 6.7	17.3±0.41	−0.5+0.58	625±10.3	−14±12.1
39-5-12-2-3-1	3.2	60.8	−12.1	19.0±0.50	+1.2±0.65	568± 6.5	−71± 8.9
39-5-3-2-5-4	5.6	105.2	+35.3	18.8±0.34	+1.0±0.52	596± 7.9	−43±10.1
39-5-3-2-5-5	4.4	89.3	+16.4	20.3±0.57	+2.5±0.71	617±10.7	−22±12.4
39-5-3-2-6-3	6.0	117.6	+44.7	19.6±0.39	+1.8±0.57	600± 6.8	−39± 9.3
39-5-3-2-9-1	4.6	85.6	+12.7	18.6±0.43	+0.8±0.59	585± 8.8	−54±10.9
39-5-4-1-9-1	4.2	72.9	0	17.4±0.39	−0.4±0.57	579±10.1	−60±11.9
39-5-4-3-6-1	3.2	52.5	−20.4	16.4±0.56	−1.4±0.69	614±13.6	−25±14.9
39-5-12-1-1-1	3.2	51.8	−19.1	16.2±0.33	−1.6±0.51	574±14.8	−65±16.1
39-5-12-2-4-3	3.0	47.4	−25.5	15.8±0.48	−2.0±0.63	564±17.9	−75±18.9
39-5-12-2-6-1	3.6	67.3	− 5.6	18.7±0.81	+0.9±0.96	568±14.3	−71±15.6
39-5-12-2-9-3	4.2	70.1	− 2.8	16.7±0.36	−1.1±0.54	526± 9.7	−113±11.5

TABLE 4

YIELD AND TYPE OF FRUITS PRODUCED BY INBRED KLONDIKE STRAINS COMPARED WITH COMMERCIAL KLONDIKE; 1932

Pedigree	Strain No.	Average number of fruits per plant	Yield in pounds		Weight per fruit in pounds		Fruit shape index	
			Per plant	Difference	Mean	Difference	Mean	Difference
Klondike (commercial)	....	4.1	70.8	....	17.27±0.261	....	606±3.69	....
39-5-3-2-1-1-5	1*	5.0	75.2	+ 4.4	14.86±0.265	−2.41±0.388	601±5.15	− 5±6.33
39-5-3-2-1-2-2	2	4.5	73.3	+ 2.5	16.26±0.299	−1.01±0.409	562±3.50	−44±5.68
39-5-3-2-5-1-1	3	4.3	82.9	+12.1	19.21±0.358	+1.94±0.584	548±5.39	−58±6.54
39-5-3-2-5-2-5	4	4.8	86.1	+15.3	17.88±0.295	+0.61±0.407	557±6.21	−49±7.22
39-5-3-2-5-3-2	5	4.5	82.5	+11.7	18.33±0.365	+1.06±0.588	552±6.41	−54±7.45
39-5-3-2-6-1-5	6	5.1	88.1	+17.3	17.18±0.288	−0.09±0.401	571±5.41	−35±6.56
39-5-3-2-6-2-2	7	4.2	73.7	+ 2.9	17.07±0.364	−0.20±0.587	573±5.80	−33±6.87
39-5-4-3-6-1-18	8	3.6	68.5	− 2.3	19.38±0.402	+2.11±0.400	604±5.90	− 2±6.96
39-5-4-3-6-1-19	9	3.3	58.6	−12.2	17.20±0.361	−0.07±0.586	609±6.40	+ 3±7.43
39-5-4-3-6-1-21	10	2.9	54.5	−16.3	18.92±0.349	+1.65±0.449	599±5.50	− 7±6.61

* In 1931, the ten best strains were assigned the permanent numbers given in this column.

Results in 1931.—Whereas, in 1930, strains inbred for one to four generations were compared with commercial stocks, in 1931 commercial stocks were compared with 20 strains inbred for five generations. As in 1930, inbred strains tended to yield more fruits per plant than commercial stock, this being true of 13 of the 20 strains tested (table 3). The average yield per plant of commercial stock was significantly less in 1931 than in 1930. Extremely hot weather during July, 1931, apparently tended to interfere with fruit setting. The inbred strains varied considerably, but inbreeding evidently did not tend to decrease consistently the number of fruits per plant.

Results in 1932.—Though only 10 inbred strains were compared with commercial stocks in 1932, the exact number of melons produced by each of the 237 plants was recorded; and in table 4 in the column headed "Average number of fruits per plant," the figures represent the computed mean. Of the 10 strains tested, 7 produced more fruits per plant than commercial stock, again indicating that many inbred strains produce as many as commercial stock, or more.

Discussion.—According to the data above, our present seed supply of inbred Klondike strains may be safely increased and distributed through seed trade channels without danger of decreasing the number of fruits per plant. In fact, statistics[23] show that for watermelons the average number of fruits for the United States in 1930 was only 322 per acre. During the same period (table 5), the average number in Imperial Valley was 654, while in other districts in California it was 775 per acre.

TABLE 5

NUMBER OF WATERMELON FRUITS PER ACRE FOR THE IMPORTANT DISTRICTS OF THE UNITED STATES

State	Number of fruits per acre*			
	1928	1929	1930	Average
Georgia	300	340	350	330
Florida	275	288	273	279
Texas	250	180	235	222
South Carolina	300	330	325	318
California	691	732	720	714
Alabama	250	320	380	317
Missouri	286	272	190	249
North Carolina	300	180	270	250

* Data taken from a published summary[23] of the Bureau of Agricultural Economics, United States Department of Agriculture.

With a planting distance of 9 by 6 feet and thinning to one plant per hill, 660 plants may be produced on one acre. Since many growers thin to 2 plants per hill, with 1,320 plants per acre they should be able to produce 2,500 fruits. With improved Klondike strains the average for California might well be increased to 1,000 fruits per acre. In an extensive planting in Imperial Valley in 1932, comparing commercial stock with 10 of our inbred strains, a significant difference noted by the cooperator was that the inbred strains produced relatively few cull fruits. Experience at Davis has shown this observation to be correct. Inbreeding and selection tend to eliminate inferior plants and to allow for gradual improvement within the variety. Seedsmen could well afford to devote considerable attention to watermelon breeding.

TOTAL YIELD IN POUNDS PER PLANT

The total yield per plant, in pounds, is determined both by the weight and by the number of the fruits. Some small-fruited varieties such as Winter Queen and Baby Delight (Hungarian Honey) are commonly known to produce many more fruits per plant than such large-fruited varieties as Tom Watson and Thurmond Grey. The fact that a plant produces relatively few melons does not necessarily indicate a low total yield.

Results in 1930.—As it was physically impracticable to record the actual yield of each plant separately in 1930, the data represent only mathematical averages. Of 14 strains under comparison (table 2), 11 produced a greater total yield than the commercial stock, and only 2 of the remaining 3 produced significantly less. There is, furthermore, no consistent evidence that continued inbreeding of a particular strain causes any significant decrease in total yield. In the progeny of 39–9, a gradual increase in average plant yield appeared with continued inbreeding, even though average fruit weight remained fairly constant. In the inbred progeny of strain 39–5, an additional generation of inbreeding sometimes lowered and sometimes increased total yield per plant. Evidently, then, total plant yield, expressed in terms of fruit weight, was not significantly lowered by inbreeding.

Results in 1931.—Average yield per plant in 1931 was determined in the same manner as in 1930 (table 3). Of 20 strains tested, 11 produced a higher and 8 a lower yield than commercial stock. The 5 progeny of strain 39–5–12 consistently produced a lower yield; and two strains, 39–5–12–1–1–1 and 39–5–12–2–4–3, also produced fruits significantly smaller than commercial stock. These strains have been discarded. With two exceptions, the progeny of strain 39–5–3–2 consistently produced a high average plant yield; and several seed companies are now increasing the seed supply of this strain for distribution as California Klondike.

Results in 1932.—The progeny of strains 39–5–3–2 and 39–5–4–3 were compared with commercial stock in 1932 (table 4), but the yield of each plant was exactly determined by individual records. As the data show, the progeny of the former strain yielded more and that of the latter strain less than commercial stock. Since the progeny of strain 39–5–4–3 tend to mature fruit somewhat earlier than any others, inbreeding of this strain will be continued, its fruit being also of desirable type, size, and quality for Imperial Valley conditions.

AVERAGE WEIGHT PER FRUIT

As previously stated, growers in Imperial Valley prefer a smaller fruit than those in districts where the watermelon crop matures later. Often a relatively small-fruited strain produces more melons per plant than one larger fruited; hence there might be no significant decrease in total yield per plant even though the melons were of smaller size. An ideal Klondike type for Imperial Valley conditions would be a strain producing fruits of uniform type and high quality and maturing three to four per plant with an average weight of 18 to 20 pounds. In districts where the fruit ripens later than in Imperial Valley, the same general type is desired; but growers prefer a strain producing an average fruit weight of 22 to 25 pounds.

Results in 1930.—As each melon was weighed separately, the average weight could be ascertained and statistical formulas applied in order to evaluate the difference between inbred strains and commercial stock.

From the original data for each strain were prepared class-frequency tables showing the weight of individual fruits. The means were then computed. The standard deviation as well as the probable error of the mean was determined by the usual method, and the probable error of the differences was computed. The difference in mean weight was considered significant only when at least three times the probable error of the difference.

The data derived from the 1930 trials, as presented in table 2, indicate a general tendency for the mean fruit weight of inbred strains to fall below that for commercial stock. This decrease was significant in only 6 of the 15 strains tested, and 4 of these showed an increase in plant yield because more melons were produced than in commercial stock. Because strains 39–5–12 and 39–5–3–3 produced such small fruits, they and their progeny have been discarded.

Though none of the inbred strains produced heavier fruit than commercial stock, a study of the frequency distribution based on actual fruit weight shows greater uniformity among inbred strains than in

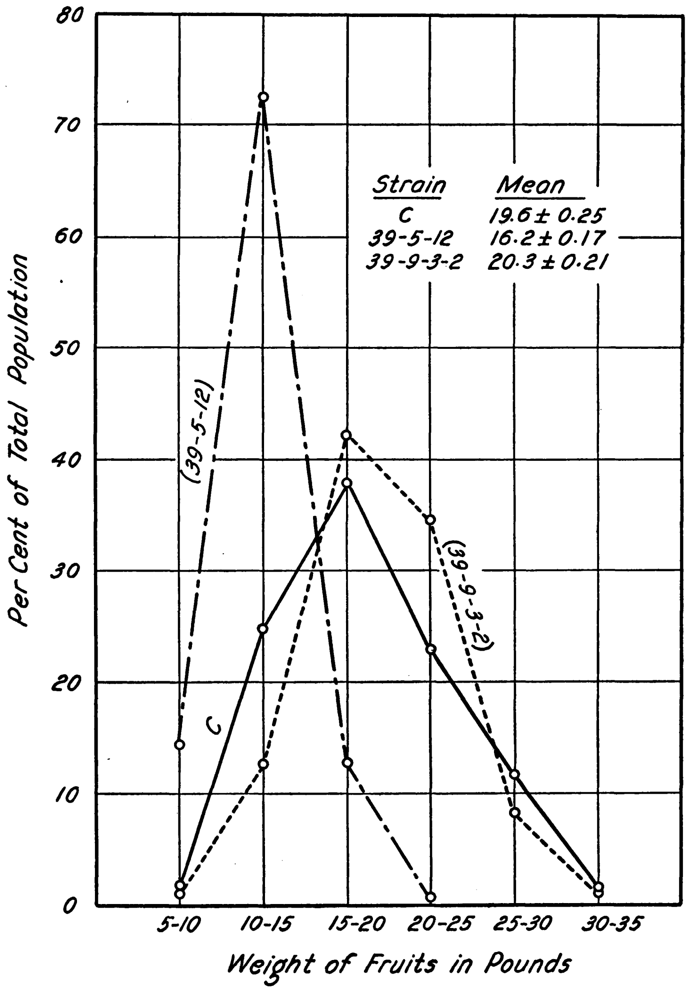

Fig. 8.—Frequency distribution of commercial Klondike, *C*, and two inbred strains, on the basis of individual fruit weight; 1930 data.

commercial stock. This was marked in 39–5–12, a small-fruited strain, and evident in 39–9–3–2, the largest-fruited strain tested in 1930 (fig. 8). Inbreeding apparently serves to isolate both small and large-fruited strains and tends to establish uniformity with respect to fruit size.

Results in 1931.—In 1931, two strains produced significantly heavier and two significantly lighter fruit than commercial stock (table 3). Whereas strain 39–5–12–1–1–1 has been discarded on account of inferior quality, the seed supply of strain 39–5–4–3–6–1 has been increased for distribution because the fruit seems to mature a few days earlier than among other strains. Though the mean weight of fruits of inbred strains seldom differed significantly from that of commercial stock, statistical examination consistently indicated that the former were much more uniform, with a much smaller standard deviation, than the latter.

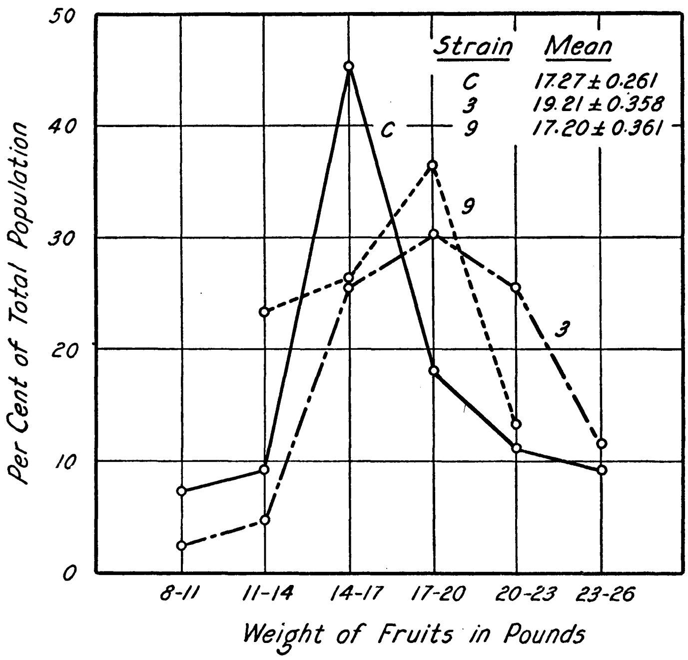

Fig. 9.—Frequency distribution of commercial Klondike, *C*, and two inbred strains, on the basis of individual fruit weight; 1932 data.

Results in 1932.—The strains tested in 1932 had been inbred for six generations (table 4). Of 10 inbred strains, 3 produced heavier and only 1 lighter fruit than commercial stock. Almost without exception, the fruits of the former were much more uniform in weight, than the latter. The frequency distribution of strains 3 and 9 is compared in figure 9, with commercial stock *C*, indicating the more pronounced fruit weight uniformity among the inbred strains. At present, strain 3 seems to be the most desirable of the many inbred strains for seed increase and distribution to the trade. It will be later described in detail.

Discussion.—On the basis of mean fruit weight in combination with many other desirable fruit and vine characteristics, the seed supply of strains 1 and 2, each inbred for six generations, will be increased and distributed to the trade with a recommendation for truck gardening and home use. Although somewhat small for commercial use in the important districts of the state, the fruits are of extremely high quality. Strain 3 appears ideal for Imperial Valley conditions, being of desirable weight, shape, and quality, with satisfactory yield per plant. When tested in Imperial Valley in 1932 in competition with nine other inbred strains and commercial stock, it manifested qualities desirable for that district. At Davis in 1932, one plant of strain 3 produced seven mature melons, weighing 16, 16, 23, 23, 24, 25, and 26 pounds respectively, an average weight of 21.7 pounds. As three of these melons resulted from artificial self-pollination this new strain will probably continue to produce large fruit and be adapted to districts where fruit matures later than in Imperial Valley.

FRUIT-SHAPE INDEX

The lack of desirable fruit-shape uniformity in commercial Klondike stock has led many growers to conclude that this variety is "running out" with continued culture in California. In some districts this lack of uniformity has led to the substitution of certain other varieties lower in flesh quality than Klondike. In commercial fields, quite diverse fruit types are common, some long and slender, others decidedly oval to nearly round. Whether this variation results entirely from segregation or from varietal mixtures is not known, but certainly we need strains that will produce fruits of more uniform shape.

Fruit-shape index was determined by dividing the equatorial by the polar diameter. Individual fruits were measured to the nearest half inch. Thus, if a fruit measured 16 by 8 inches, the shape index (ignoring the decimal point) was 500. Desirable fruit-shape index for the Klondike variety lies between 500 and 625. If less than 500, the fruit is considered too slender; if more than 625, too blocky. During these investigations, fruits have been found with shape indexes as low as 388 (18 by 7 inches) and as high as 1,333 (9 by 12 inches). Inbreeding tends to isolate these undesirable types and permits their elimination. Fruits of uniform weight and shape are easily loaded for shipment and reach the market with minimum bruising and breakage. They also make a more attractive display.

Results in 1930.—The fruit-shape index of fourteen inbred strains is presented in table 2. With three exceptions, the differences were sig-

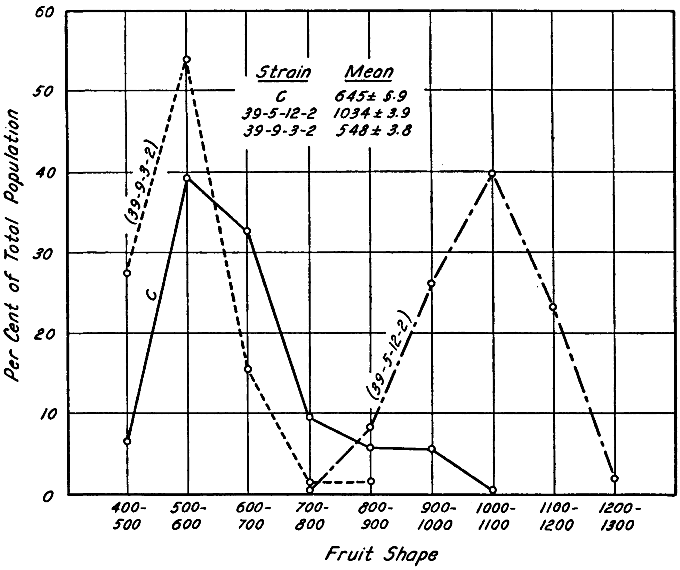

Fig. 10.—Frequency distribution, based on the ratio of equatorial to polar fruit diameter, of commercial Klondike, *C*, and two inbred strains; 1930 data.

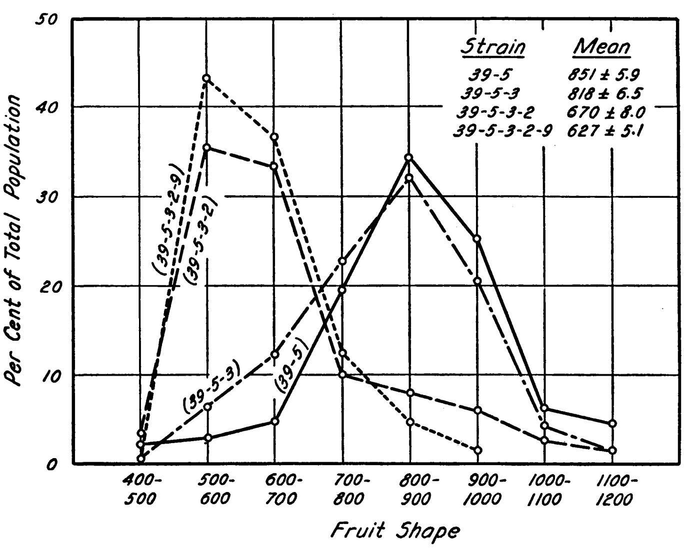

Fig. 11.—Frequency distribution, according to fruit shape, of strains inbred for one, two, three, and four generations, showing the effects of selection toward oblong fruits; 1930 data.

nificant. One should note that within strains 39–5 and 39–9, selections were purposely made for oblong fruit shape. With continued inbreeding of strain 39–5 to 39–5–3–2–9 and with conscious selection of oblong fruits, the fruit-shape index decreased from 851 ± 5.9 to 627 ± 3.8. Four generations of inbreeding, with particular attention to desirable fruit shape, tended to eliminate the undesirable types. With respect to fruit shape, among commercial stocks and two strains (39–5–12–2 and 39–9–3–2) each inbred for three generations, figure 10 indicates that this character was becoming fixed. The spread among commercial stock varied from 400 to 1,100, that of 39–5–12–2 from 700 to 1,300, and that of 39–9–3–2 from 400 to 900.

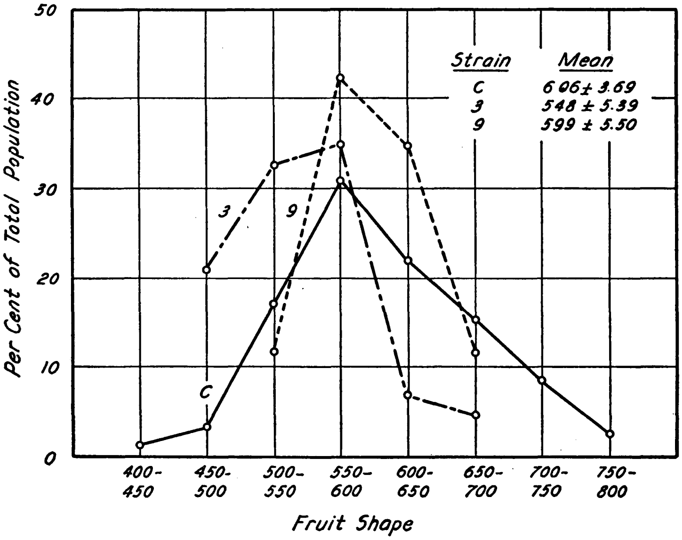

Fig. 12.—Frequency distribution, according to fruit shape, of commercial Klondike, *C*, and strains 3 and 9; 1932 data.

The frequency distribution of 39–5, 39–5–3, 39–5–3–2, and 39–5–3–2–9, as indicated in figure 11, shows that continued selection and inbreeding for four generations tended to stabilize fruit shape. The spread of 39–5 was from 400 to 1,200 (mean 851 ± 5.9) ; that of 39–5–3–2–9, from 400 to 1,000 (mean 627±5.1), with 80 per cent of the fruits indexing between 500 and 700.

Results in 1931.—Of 20 strains tested, all were of more desirable fruit shape than commercial stocks (table 3). The differences were less pronounced than in 1930, because all the inbred strains had been inbred for five generations, with selection for desirable type. All the strains, in fact, showed a fruit-shape index between 500 and 625. Undesirable fruit types had been eliminated.

Results in 1932.—The ten strains tested in 1932 had been inbred for six generations (table 4), and all were within the range of desirable fruit shape. Six strains differed significantly from commercial stocks in fruit shape, all being more desirable. In figure 12, commercial stock *C* shows a range from 400 to 800 (standard deviation 70.9); strain 3 (39–5–3–2–5–1–1) from 450 to 700 (standard deviation 54.2); and strain 9 (39–5–4–3–6–1–22) from 500 to 700 (standard deviation 42.1). According to these data, six generations of inbreeding, with elimination of undesirable fruit types, served to fix the character for desirable type. As indicated earlier, strain 3 has proved well adapted to commercial production.

DISCUSSION OF INBREEDING EFFECTS AND RESULTS

Inbreeding of Klondike watermelons, therefore, does not consistently lessen plant vigor, number of fruits, nor total yield per plant, and may serve to isolate strains that produce fruits of weight and type equal or superior to commercial stocks. The practice of inbreeding does not serve to create new strains; rather, it improves the stocks by uncovering certain undesirable types that should be eliminated.

One should note that certain inbred strains seem actually to have lost vigor, as expressed in terms of weight and number of fruits per plant. Such strains have been discarded, for the purpose of our breeding work is primarily to improve commercial stocks, not to examine the genetic constitution of the inbred strains. Certain strains, however, now inbred for six generations, are no less vigorous than commercial stock. The seed supply of such strains has been or will be increased for distribution to growers and seedsmen, with the assurance that it will produce more uniform fruits of higher flesh quality than commercial stock and will yield equally well. Evidently, furthermore, in commercial stocks, relatively few of the genetic factors governing plant vigor exist in the heterozygous condition, for the inbred strains tend to fluctuate only slightly from the yield of commercial stocks. If a large number of the vigor factors were in the heterozygous condition, yield fluctuations would probably be greater.

No data have been presented to indicate the effects of inbreeding on fruit-skin color; on rind thickness and toughness; on flesh color, texture, solidity, and sugar content; nor on seed size or seed coat color. Obviously considerable diversity exists among these characters, and though certain of them have received well-merited consideration, their uniformity and variation among inbred strains could not always be measured accurately.

The late Dr. Rosa at first made particular effort to improve flesh quality and at the same time to incorporate the black-seeded character. Though all the more desirable inbred strains now produce black seeds, this character is not considered so important as formerly. The seeds of the inbred strains are significantly smaller, with more per pound, than in commercial stocks (table 6). This character is of some importance, for it increases the acreage that may be planted with a certain quantity

TABLE 6

VARIATION IN NUMBER OF SEEDS PER POUND AMONG COMMERCIAL AND INBRED KLONDIKE WATERMELON STRAINS

Year grown	Place grown	Stock	Seeds per pound
1930	Los Angeles	Commercial	6,019
1930	Los Angeles	39-5-3-2-9-op*	11,222
1931	Los Angeles	Commercial	8,799
1931	Modesto	Commercial	7,149
1932	Los Angeles	Commercial	5,748
1932	Los Angeles	39-5-4-3-6-1-3	11,604
1932	Los Banos	Commercial	6,864
1932	Los Banos	39-5-3-2-1-1-5	9,243
1932	Modesto	39-5-3-2-5-op-op	8,962
1932	Modesto	39-5-4-3-6-1-6	8,853
1932	Davis	Commercial	7,113
1932	Davis	39-5-3-2-1-1-op	8,449
1932	Davis	39-5-4-3-6-1-18	9,265

* The designation "op" means open-pollinated.

of seed. With respect to flesh characters, much uncontrollable variation exists because not all fruits can be harvested at the same stage of maturity. Hence the uniformity of this character has been measured, relatively, by a large number of fruits of all strains. The importance of a rind strong enough to withstand shipping has been realized; and, though the most desirable inbred strains produce relatively thin rinds (¼ to ½ inch), tests have shown that the fruits will endure rough handling with minimum breakage.

DESCRIPTION OF IMPROVED STRAINS

Cooperative field tests of the more desirable inbred strains, with commercial stocks as checks, have been made annually since 1930. These tests have been conducted with growers and seedsmen in Imperial, Riverside, Los Angeles, Kern, Tulare, Stanislaus, San Joaquin, and Butte counties. The advisability of these widely separated tests is obvious.

Though the description of the strains is based, primarily, upon their comparative response at Davis, these outlying tests have often brought to light some desirable and some undesirable characters not evident here. The most complete of the outlying tests have been conducted in the Imperial Valley for two reasons: first, hundreds of acres there are not yet severely infested with the wilt organism (*Fusarium niveum*); and second, during 1928, 1929, and 1930 approximately 62 per cent of the state's watermelon acreage was located there.

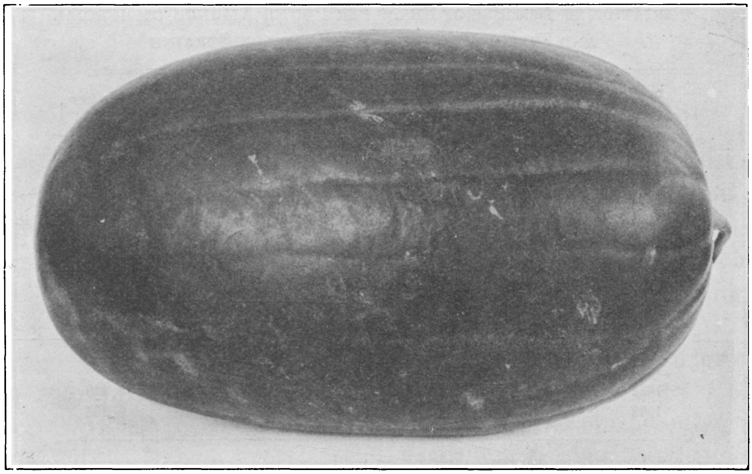

Fig. 13.—A typical mature fruit of California Klondike strain No. 3. Weight, 20 pounds; shape index 581 (15.5 × 9 inches); skin dark green; suture slight; rind thickness ⅜ inch; flesh deep red, of excellent texture and high sugar content; seeds small, with black seed coat.

In order to avoid confusion, the improved strains are designated as California Klondike, and seed has been and will be distributed under this varietal name. A brief description of four strains of the California Klondike watermelon follows (table 4).

Strain 1.—Relatively small fruited; average weight 15 pounds; shape index, 601; skin dark green and smooth, with very slight suture; rind very thin (¼ to ⅜ inch) and somewhat brittle; flesh deep red, of excellent texture and high sugar content; seeds small and black; very prolific; recommended to market gardeners and for home planting; fruits too small and rind too tender for extensive commercial use.

Strain 3.—Relatively large fruited; average weight, 19 pounds; shape index 548 (fig. 13); skin very dark green with shallow suture; rind of medium thickness (¼ to ½ inch), sufficiently tough for long-distance shipment; flesh very solid, deep red, of excellent texture and high sugar content; seeds small and black; prolific; uniform, producing very few culls; one plant of this strain produced seven ideal fruits in 1932, with an average weight of 21.6 pounds; recommended to commercial planters wherever the Klondike is now grown, and to market gardeners who prefer a larger melon than strain 1.

Strain 8.—This strain, though somewhat inferior in flesh quality, might well replace Angeleno as a shipping melon to such distant points as Canada. Ideal type with deep bluish-green skin and extremely tough rind. Flesh slightly hard, but sweet.

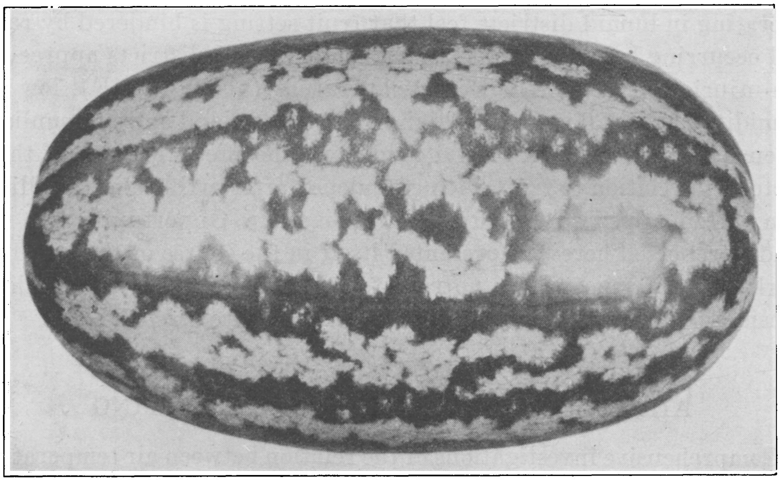

Fig. 14.—Striped Klondike, a relatively recent commercial selection, at present gaining in popularity in the San Joaquin and Sacramento valleys.

Strain 9.—Fruits of this strain, in 1931, appeared to mature earlier than any other strain both in the Imperial Valley and at Davis. Seedsmen report it to be early maturing, but this point should be more definitely ascertained. The fruit is of desirable type and quality, and seed is available.

Striped Klondike.—This variety (fig. 14), now advertised by certain seed companies, is said to have been originally selected by a grower in interior California about ten years ago in a field of commercial Klondike. Continued mass selection by growers for the striped-skin character, large fruit, and high flesh quality has isolated a strain remarkably uniform as to skin color. At Davis, in 1932, approximately 97 per cent of the plants of this variety produced striped fruit. Fruit size and shape, rind thickness, flesh quality, and seed characters varied somewhat; but this is to be expected in a variety not kept pure by continued self-pollination. At Davis, the flesh quality was somewhat inferior to that of the same variety grown on lighter soil types in San Joaquin and Stanislaus counties, and was slightly inferior to ordinary commercial Klondike. As Striped Klondike seems to be increasingly popular, breeding work to purify it further is now under way.

CONDITIONS INFLUENCING FRUIT SETTING

Knowledge of the conditions that influence fruit-setting tendencies in *Citrullus vulgaris* is limited chiefly to field observations. Growers operating in humid districts feel that fruit setting is hindered by rainfall occurring between 6 and 11 a.m. Those in arid districts appreciate the injurious effects of high air temperature (above 100° F), low air humidity (below 20 per cent), high wind velocity, and extreme sunlight intensity. In Iowa under humid conditions, the effects of some of these factors, in relation to fruit-setting tendency after artificial self-pollination, often appeared worthy of investigation. Opportunity for the studies reported herewith presented itself in the course of the breeding work in California, where no rain fell during pollination and where considerable variation in forenoon air temperature existed.

AIR TEMPERATURE AND FRUIT SETTING

Comprehensive investigations of the relation between air temperature and fruit setting were initiated in 1931, after the experience in 1930 had strongly indicated that fruit setting might have been influenced by abnormally high temperatures during the morning hours.

Results in 1931.—Artificial self-pollination of 10 Klondike strains, each inbred for five generations, began on June 20 and continued until July 11. Pollination of the same strains, planted considerably later, began on August 3 and terminated on August 16. The date, time, and result of each pollination were recorded. Obviously, not all the selfed flowers set fruit—the number borne by individual plants is much too high; but with a relatively large number of flowers involved, and with random selections made each day, the results have probably some significance.

The results of this study appear in table 7, showing the number of pollinations made each day, and the percentage that set fruit, with corresponding air temperatures during the morning hours, from 8 to 10, 10 to 12, and 8 to 12 inclusive. Of 435 self-pollinations made during June and July, only 70 (or 16.1 per cent) set fruit. The percentage fruit setting, per day, varied from 0.0 in seven instances to as high as 33.3 on June 21. For purposes of comparison, attention is directed to results secured between June 24, when 32, and July 8, when 53 flowers were selfed. Comparison of percentage set on each day with that on the day immediately preceding or following, does not always indicate that hot

TABLE 7

WEATHER CONDITIONS IN RELATION TO FRUIT SETTING IN INBRED KLONDIKE WATERMELONS; 1931

Date		Pollinations		Average air temperature, degrees Fahr.			Relative per cent humidity of the air at 12 m.
		Number	Per cent successful	8 a.m. to 10 a.m.	10 a.m. to 12 m.	8 a.m. to 12 m.	
June	20	9	0.0	60	70	64	37
	21	9	33.3	62	75	67	47
	22	16	0.0	69	82	74	34
	23	17	0.0	66	79	71	26
	24	32	18.7	82	85	84	23
	25	25	0.0	83	98	89	20
	26	43	13.9	84	94	88	23
	27	22	22.7	75	82	78	35
	28	32	31.2	68	80	73	35
	29	25	8.0	76	85	80	14
	30	24	4.1	78	88	82	17
July	1	20	10.0	83	92	87	17
	2	17	11.8	80	94	86	26
	3	23	26.1	87	97	91	15
	4	18	0.0	92	102	96	12
	5	2	0.0	86	104	93	22
	6	7	0.0	81	89	85	26
	8	53	24.5	84	94	88	22
	9	14	21.4	82	95	87	17
	10	16	31.3	86	96	90	14
	11	11	27.3	80	95	88	21
Average		....	*16.1*	*79*	*91*	*83*	*24*
August	3	7	28.5	70	83	75	36
	4	2	100.0	68	84	74	40
	5	7	42.8	70	84	76	35
	6	9	22.2	68	80	72	36
	7	12	41.6	64	82	71	36
	8	12	41.6	66	82	72	31
	9	11	27.2	69	84	75	33
	10	13	38.4	65	80	71	36
	11	8	25.0	73	86	78	34
	12	11	54.5	78	89	82	24
	13	15	20.0	79	87	82	32
	14	11	18.1	68	80	73	44
	15	9	33.3	71	84	77	30
	16	2	50.0	80	96	87	23
Average		....	*35.6*	*71*	*84*	*76*	*34*

TABLE 8

EFFECT OF AIR TEMPERATURE AND HUMIDITY ON FRUIT SETTING, IN INBRED KLONDIKE WATERMELONS; 1932

Date	Number of pollinations	Per cent successful pollinations	Hourly and average air temperatures, degrees Fahr.									Hourly and average air humidity, per cent								
			6 a.m.	7 a.m.	8 a.m.	9 a.m.	10 a.m.	11 a.m.	12 m.	Mean 6 a.m. to 12 m.	Mean 12 m. to 6 p.m.	6 a.m.	7 a.m.	8 a.m.	9 a.m.	10 a.m.	11 a.m.	12 m.	Mean 6 a.m. to 12 m.	Mean 12 m. to 6 p.m.
July 5	4	0.0	76	84	87	94	95	97	97	90	99	46	39	36	31	26	26	26	33	37
6	1	100.0	51	55	59	64	70	76	87	63	100	75	68	65	60	50	37	32	55	25
7	4	25.0	54	57	61	66	76	84	92	70	103	72	67	64	54	46	42	34	53	25
8	24	50.0	56	64	70	76	87	94	97	78	105	62	55	47	26	12	12	12	32	21
9	22	54.5	58	64	70	74	76	78	77	71	77	64	58	54	54	52	50	48	54	51
10	23	65.2	45	50	56	60	64	66	70	59	81	67	64	60	55	50	37	27	51	29
11	34	58.8	50	50	53	57	64	67	71	59	80	73	67	62	54	45	40	36	54	35
12	55	52.7	48	53	58	64	70	75	82	64	81	67	63	60	53	36	34	34	49	41
13	117	61.6	52	52	54	56	60	63	66	58	76	75	72	67	65	60	55	50	63	46
14	154	58.4	51	56	60	66	73	78	82	67	88	70	65	60	48	43	38	35	51	34
15	88	40.9	55	62	68	75	80	84	87	73	90	63	60	50	44	39	33	25	45	32
16	93	38.7	53	58	65	73	76	83	87	71	93	68	63	55	47	40	32	25	47	30
17	84	50.0	54	57	64	70	76	84	87	70	85	70	65	58	45	35	35	35	49	40
18	49	47.0	54	55	56	62	65	67	71	61	71	73	70	66	65	60	55	55	63	53
19	2	100.0	46	53	57	64	70	76	81	64	91	74	68	62	54	37	27	27	50	25
20	0	....	54	57	67	80	84	87	92	74	100	63	42	35	31	26	23	20	34	25
21	3	33.3	52	57	64	73	80	86	94	75	95	66	50	52	35	29	19	19	39	26
22	7	85.5	52	57	63	72	76	83	87	70	94	70	66	55	47	40	32	31	49	32
23	3	0.0	52	56	65	72	77	85	89	71	95	67	62	55	46	40	33	24	47	28
Averages	....	*51.8*	*53*	*58*	*63*	*69*	*75*	*80*	*84*	*69*	*90*	*68*	*61*	*56*	*48*	*40*	*35*	*31*	*48*	*33*

weather reduced fruit setting. The entire period was abnormally warm, with many desiccating winds of high velocity. Attention, however, is called to comparative fruit setting in relation to temperature on June 24 and 25, June 26 and 27, June 28 and 29, and July 3 and 4.

Between August 3 and 16, inclusive, 129 pollinations were made, of which 35.6 per cent set fruit. The air temperature during this period was lower than during the pollinating period in June and July, and the respective averages were also lower.

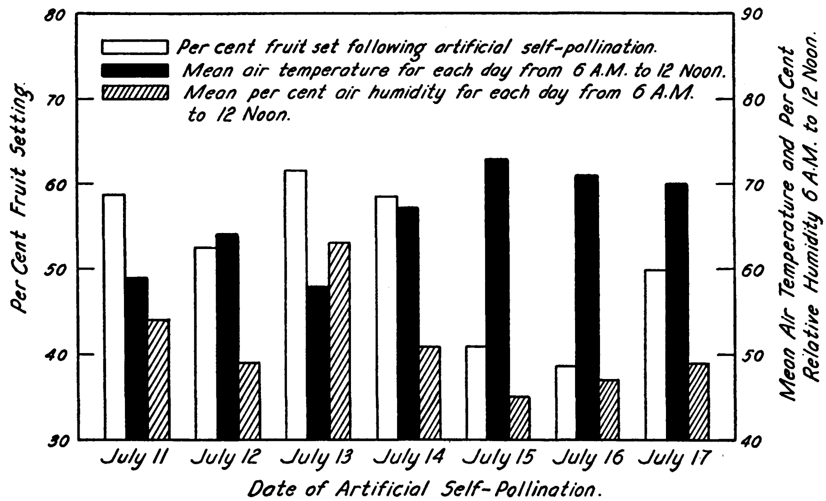

Fig. 15.—The apparent relation of air temperature and air humidity from 6 a.m. to 12 noon, to rate of fruit setting after artificial self-pollination of inbred Klondike strains at Davis, 1932.

Results in 1932.—Investigation of the temperature effects in 1932 were continued more extensively than in 1931, although all pollinations were made during 19 days, from July 5 to 23, inclusive. The means for the periods 6 a.m. to 12 noon, and 12 noon to 6 p.m. are listed in table 8. Marked variation in temperature occurred throughout the pollinating period: that at 6 a.m. varied from 45° to 76° F, that at 9 a.m. from 56° to 94°, and that at 12 noon from 66° to 97°. In several instances, high percentage set was directly related to low average air temperature from 6 a.m. to 12 noon. This relation is clearly indicated in figure 15, where the data for each day are compared with those for both the preceding and following day. The highest percentage set (61.6) occurred on July 13, when the temperature at 12 noon was only 66° F and the average for the morning was only 58° F, the lowest during the 19-day period. On 10 different days the average air temperature from 6 to 12 was higher, and on 8 days it was lower than the average (69° F) of the entire pollinating period. During the former group, the set was 44 per cent; during the latter, 58 per cent, again indicating that fruit-setting tendency was greater during cool weather.

AIR HUMIDITY AND FRUIT SETTING

Under arid climatic conditions, the relative humidity of the air varies considerably from hour to hour during the day and from day to day. At Davis, this is particularly true during the summer months, when the humidity may be reduced from 62 per cent at 6 a.m. to 12 per cent by 12 noon. Such decided fluctuations might affect fruit-setting tendencies.

Results in 1931.—Although hourly record of air humidity was not made in 1931, table 7 shows the actual humidity at 12 noon for each day of the pollinating period, with the forenoon temperature for the early and late pollinating periods. During the June and July pollinating period the mean humidity at noon was 24 per cent, while the percentage set was 16.1. During the August period the mean humidity increased to 34, the set to 35.6.

Results in 1932.—Air humidity was recorded hourly during the pollinating period; and the various means, indicated in table 8, were determined. The percentage humidity at 6 a.m. on the different dates varied from 46 to 75; at 9 a.m. from 26 to 65; and at noon from 12 to 55. The mean humidity from 6 a.m. to 12 noon varied from 33 to 63; that from 12 noon to 6 p.m., from 21 to 53.

The relation of high percentage set to high relative humidity is more evident when only the morning hours are considered. Apparently the air humidity after 1 p.m. exerts little influence upon fruit setting.

TABLE 9

AIR TEMPERATURE AND HUMIDITY IN RELATION TO FRUIT SETTING IN KLONDIKE WATERMELONS; 1931 AND 1932

Period	Total self-pollinations	Per cent fruit set	Air temperature, degrees Fahr.			Relative humidity, per cent		
			Forenoon	Afternoon	24-hour period	Forenoon	Afternoon	24-hour period
June 20 to July 11, 1931	435	16.1	83	93	84	26	31	29
August 3 to 16, 1931	129	35.6	76	87	80	34	32	33
July 5 to 23, 1932	767	51.8	69	90	78	48	33	40

Between July 11 and 17, inclusive, high percentage set was almost constantly related to high relative humidity, this in turn (fig. 15) being correlated with low air temperature. Apparently, low air temperature and high relative humidity jointly encourage high percentage set after selfing. The interrelations of temperature, humidity, and fruit-setting tendency are shown in table 9, where these conditioning factors for 1931 and 1932 are compared. The data show that the morning temperature was lower and the humidity higher during 1932 than in 1931, with a corresponding increase in fruit-setting percentage in 1932.

FRUIT SETTING AS INFLUENCED BY TIME OF POLLINATION

With each self-pollination, record was made of the hour, vigor of runner, size of ovary, and receptivity of stigma. During 1931, pollinations were made between 6 a.m. and 1 p.m. Table 10 summarizes the data for 1931 and 1932. During June and July, 1931, fruit setting showed a very slight, probably insignificant tendency, to increase

TABLE 10

TIME OF DAY AT WHICH SELF-POLLINATIONS WERE MADE IN RELATION TO FRUIT SETTING IN KLONDIKE WATERMELONS

Time of day	Trial* No.	Total pollinations	Total fruits set	Percentage of fruits set
6 to 7 a.m.	1	13	2	13.1
7 to 8 a.m.	1	152	22	14.5
8 to 9 a.m.	1	220	37	16.8
9 to 10 a.m.	1	78	13	16.7
10 to 11 a.m.	1	17	3	17.6
6 to 7 a.m.	2	7	2	28.6
7 to 8 a.m.	2	23	8	34.8
8 to 9 a.m.	2	34	15	44.1
9 to 10 a.m.	2	35	16	35.5
10 to 11 a.m.	2	34	15	44.1
6 to 7 a.m.	3	77	36	46.7
7 to 8 a.m.	3	168	85	50.6
8 to 9 a.m.	3	177	95	53.7
9 to 10 a.m.	3	176	73	41.5
10 to 11 a.m.	3	113	45	39.8
11 to 12 a.m.	3	70	29	40.1
12 to 1 p.m.	3	8	0	0.0
6 to 9 a.m.	3	422	216	51.2
9 a.m. to 12 m.	3	359	147	40.9

* Trial 1 extended from June 20 to July 11, 1931; trial 2 from August 3 to 16, 1931; and trial 3 from July 6 to 22, 1932.

between 6 and 11 a.m. In 1932, it increased slightly between 6 and 9, with a gradual decrease in efficiency by 1 p.m. The average percentage set, in 1932, between 6 and 9 a.m. was 51.2; that between 9 and 12, only 40.9 per cent. Fertilization appears most likely to follow self-pollinations made between 7 and 11 a.m.

OVARY SIZE IN RELATION TO FRUIT SETTING

In the absence of experimental evidence, observation has indicated that fruit-setting tendency is influenced by ovary size. In 1932, therefore, as each fruit was pollinated, its relative size was recorded, being arbitrarily classified as small, medium, large, or very large. Periodically during the season each selfed fruit was examined, and record was made of all unsuccessfully fertilized. At harvest time, those that matured fruit were likewise noted. Data covering these observations appear in table 11; they indicate that small ovaries rarely set fruit, while fruit-setting tendency progressively increases among larger ovaries. Considerable time, apparently, could be saved by careful selection of the flowers to be pollinated.

TABLE 11

RELATION OF OVARY SIZE AT TIME OF POLLINATION TO FRUIT SETTING IN KLONDIKE WATERMELONS; 1932

Relative size of ovary at pollination	Total self-pollinations	Total fruits set	Percentage of fruits set
Small	70	5	7.1
Medium	363	154	42.4
Large	300	163	54.3
Very large	58	41	70.7

VIGOR OF RUNNER IN RELATION TO FRUIT-SETTING TENDENCY

The relative vigor of the individual runner bearing the pistillate flowers to be selfed was recorded. According to the data in table 12, fertilization is much more likely to occur if the fruits selected are borne on medium and strong runners rather than weak. As a matter of fact, weak runners have rarely been observed to produce large or very large pistillate flowers. Here again, time would be saved by selecting only medium or strong runners.

TABLE 12

STRENGTH OF RUNNERS BEARING FEMALE FLOWERS IN RELATION TO FRUIT SETTING IN KLONDIKE WATERMELONS; 1932

Relative strength of runner at time of pollination	Total self-pollinations	Total fruits set	Percentage of fruits set
Weak	67	19	28.4
Medium	381	145	38.0
Strong	327	168	51.4

FRUIT-SETTING TENDENCY AND EARLINESS AMONG INBRED STRAINS

Although certain strains consistently produce more fruits per plant than others, as has been demonstrated, there is no evidence that fruit-setting tendency, after self-pollination, is heritable. During 1931 and 1932, the percentage set was recorded for each of ten inbred strains, with the results presented in table 13. As previously indicated, the percentage

TABLE 13

FRUIT SETTING AND ELAPSED TIME TO FRUIT MATURITY AFTER POLLINATION IN KLONDIKE WATERMELONS, COMPARING INBRED STRAINS, 1931, WITH THEIR RESPECTIVE DAUGHTER STRAINS, 1932

Pedigree	Percentage of fruits set		Number of days between pollination and fruit maturity	
	1931	1932	1931	1932
39-5-3-2-1-1	22.7	....	42	....
39-5-3-2-1-1-5	....	50.6	....	45
39-5-3-2-1-2	29.8	....	43	....
39-5-3-2-1-2-2	....	56.5	....	47
39-5-3-2-5-1	19.1	....	45	....
39-5-3-2-5-1-1	....	47.9	....	48
39-5-3-2-5-2	13.3	....	47	....
39-5-3-2-5-2-5	....	58.3	....	50
39-5-3-2-5-3	13.5	....	49	....
39-5-3-2-5-3-2	....	60.6	....	50
39-5-3-2-6-1	19.1	....	49	....
39-5-3-2-6-1-5	....	60.9	....	51
39-5-3-2-6-2	5.0	....	44	....
39-5-3-2-6-2-2	....	54.7	....	48
39-5-3-4-2-1	19.3	....	44	....
39-5-3-4-2-1-3	....	46.8	....	48
39-5-4-3-6-1	15.2	....	39	....
39-5-4-3-6-1-18	....	27.9	....	43
39-5-4-3-6-1-19	....	54.5	....	41
39-5-4-3-6-1-21	....	17.6	....	45
39-5-12-2-3-1	16.3	....	49	....
39-5-12-2-3-1-6	....	41.2	....	53

set in 1931 was extremely low, probably because of unfavorable climatic conditions. In that year the set in strain 39–5–3–2–6–2 was only 5, while that in strain 39–5–3–2–1–2 was 29.8 per cent. The progeny of both strains, when replanted in 1932, set fruit at almost exactly the same rate. Similar instances indicate that fruit-setting tendency is probably nonheritable, although some strains normally bear more fruits per plant than others.

Since the number of days between anthesis and fruit maturity was known, data were assembled during both seasons, for each strain, to indicate the relative earliness of each. The data in table 13 show that the time between anthesis and fruit maturity varied, in 1931 from 39 to 49 days, and in 1932 from 41 to 53 days. Strain 39–5–4–3–6–1–19 does not bloom earlier but has matured fruit somewhat earlier than other inbred strains. In 1931, it was approximately 10 days earlier than commercial stock in Imperial Valley; but in 1932, under more extreme conditions, this earliness was much less apparent.

VARIETAL AND HYBRID INFLUENCES ON FRUIT-SETTING TENDENCY

Slight differences in fruit-setting tendency were found during both seasons, when several varieties and hybrids were compared (table 14). In 1931, the percentage set varied from 12.1 (new crosses) to 25.0 (Yellow-fleshed Ice Cream). In 1932, however, 56.9 per cent of the new crosses set fruit. The most notable difference in 1932 was between California Klondike and Striped Klondike. In the former variety 51.8 and in the latter only 33.2 per cent of the selfed flowers set fruit. The Striped Klondike had not been inbred, whereas the California Klondike had been inbred for six generations.

Self-pollinations have been made among the following varieties: California Klondike, Striped Klondike, Dixie Belle, Peerless, Golden Honey, Yellow-fleshed Ice Cream, Chilean, Angeleno, Baby Delight (Hungarian Honey), Georgia Rattlesnake, Thurmond Grey, Tom Watson, Pride of Muscatine, Iowa King, Iowa Belle, Grey Monarch, Wondermelon, Schochler, Winter Queen, and Black Boulder. A large number of crosses of the three wilt-resistant varieties Pride of Muscatine, Iowa Belle, and Iowa King with California Klondike, as well as numerous crosses involving many other varieties, have been successful. Fruit setting appears to depend upon proper selection of the pistillate flower with respect to ovary size and runner vigor, as well as upon the environmental conditions for a period of 5 or more hours after the pollination has been made.

Critical examination of fruit-setting tendency on individual plants of the Klondike variety has indicated the complete absence of either definite flowering peaks or definite fruiting cycles, such as those reported in *Cucumis melo* by Rosa,[18] in *Lactuca sativa* by Jones,[8] and in *Cucurbita maxima* by Bushnell.[2]

TABLE 14

FRUIT-SETTING TENDENCY OF SEVERAL WATERMELON VARIETIES AND HYBRIDS, 1931 AND 1932

Varietal designation	Year	Number of generations inbred	Total pollinations	Per cent set
California Klondike	1931	5	564	20.6
California Klondike	1932	6	767	51.8
Striped Klondike	1932	0	226	33.2
Dixie Belle	1931	3	43	18.8
Dixie Belle	1932	4	65	47.7
Peerless	1931	1	40	20.0
Peerless	1932	2	27	66.6
Golden Honey	1931	3	21	23.8
Golden Honey	1932	4	35	51.5
Yellow-fleshed Ice Cream	1931	2	16	25.0
Yellow-fleshed Ice Cream	1932	3	24	58.3
F_1 of 8 crosses	1932	....	95	46.3
New crosses*	1931	....	33	12.1
New crosses	1932	....	51	56.9
Back crosses	1931	....	22	13.9
Back crosses	1932	....	48	41.9

* Involving crosses of wilt-resistant × wilt-susceptible varieties as well as inter-crosses within the Klondike variety.

SUMMARY

Although the watermelon (*Citrullus vulgaris*) is typically monoecious, andromonoecism is common to several varieties. Parthenocarpy probably does not occur, and neither self nor cross-sterility has been encountered among the many varieties and hybrids studied.

The ratio of pistillate to staminate flowers is approximately 1:7, but the former are not always formed at every seventh node on a runner.

Pollinating technique is described, with a discussion of its adaptation under various environmental and cultural conditions.

Plant vigor, expressed in terms of vegetative growth, is not reduced by four generations of inbreeding; and no striking vigor reduction has been observed in strains inbred for six generations. Inbreeding tends to equalize and stabilize individual plant vigor.

Inbreeding tends to isolate strains producing more or fewer fruits per plant than commercial stock, but the variation in average fruit weight often compensates for reduction in number of fruits per plant.

Strains have been isolated that produce fruits of either greater or less average weight than commercial stock, and with significant decrease in standard deviation.

Total plant yield, determined by average fruit weight and number of fruits per plant, may be slightly increased or decreased by inbreeding, indicating that relatively few of the factors which govern yield are in a heterozygous condition in commercial stocks.

The commercial Klondike was found to be extremely heterozygous for the factors governing fruit shape, expressed in terms of the ratio between equatorial and polar diameter. Inbreeding permits the elimination of strains of undesirable shape, leaving genotypes significantly more uniform than commercial stock. Similarly, the standard deviation with respect to fruit shape is lowered.

Inbreeding tends to purify individual strains with respect to: fruit skin color; rind thickness and toughness; flesh color, texture, solidity, and sweetness; seed size and seed-coat color.

Several inbred strains are described with recommendations as to their adaptability to certain sections and to certain uses. California Klondike No. 1 is recommended to the market gardener or home grower; No. 3 to growers in Imperial Valley and in any other section where the Klondike is now used; No. 8 for long-distance shipment; and No. 9 for trial in Imperial Valley because of some evidence that its fruit matures earlier than commercial stock.

Fruit-setting tendency, following artificial self-pollination, is apparently influenced by air temperature and humidity between 6 a.m. and 12 noon; by the hour of pollination; by ovary size; and by relative vigor of the runners bearing the selfed flowers.

Indications are that relatively low air temperature and relatively high air humidity from early morning until noon favor fruit setting. On certain days when the morning temperature was relatively high and the humidity relatively low, none of the selfed flowers set fruit.

In general, a slightly higher percentage of pollinations results in fruit setting if made between 6 and 9 a.m. than if made between 9 a.m. and 12 noon.

The fruit-setting tendency was relatively low when small ovaries were selected, but relatively high if large ones were used. Very few fruits set if the runner bearing the pistillate flower was weak; but with stronger runners the fruit-setting tendency materially increased.

With the exception of Striped Klondike, all the varieties used responded to self-pollination in approximately the same manner. Definite flowering peaks have not been detected.

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