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EARLINESS IN F_1 HYBRID MUSKMELONS AND THEIR PARENT VARIETIES

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The present report is a study of earliness of certain F_1 hybrid muskmelons and their parent varieties as measured by the time from planting to first pistillate flower and to first ripe fruit. The plants were studied in randomized blocks in different environments provided by different planting dates, locations, and cultural methods. The data were converted into logarithms and analyzed by the analysis of variance.

The environmental effects encountered were greater than the genetic effects in determining the length of life cycle of the muskmelons in the different plantings. The plants grew faster in summer than in winter and early spring.

Most of the nine parent varieties and eleven variety hybrids performed similarly in all of the five plantings. The parent varieties could be grouped into five significantly different earliness classes on the basis of the average lengths of their total growth periods in all five plantings. Some varieties, such as the Conomon, performed similarly in both growth periods. Others, like the PMR No. 5, were early flowering and slow ripening; or, like the Kelly Sweet, were late flowering and fast ripening. The Melogold variety was more variable in different environments than were the other varieties.

Five of the F_1 variety hybrids were like the averages of their respective parents in length of period from planting to first ripe fruit. Three were significantly earlier than the averages of their respective parents; one was significantly later. Only two of the hybrids were significantly earlier than their respective early parents in total growth period. The F_1 hybrids exhibited responses that ranged from no dominance to apparent heterosis for early flowering, slow ripening, and short total growth. Partitioning the total growth period demonstrated that a hybrid could exhibit apparent heterosis for early maturity without exhibiting heterosis for either early flowering or early ripening. Such apparent heterosis probably resulted from dominance interactions rather than from heterozygosity *per se*.

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EARLINESS IN F_1 HYBRID MUSKMELONS AND THEIR PARENT VARIETIES[1]

GUY WESTON BOHN[2] and GLEN N. DAVIS[3]

INTRODUCTION

FOR SEVERAL years the United States Department of Agriculture and the University of California have developed and maintained inbred lines of muskmelons (*Cucumis melo* L.) resistant to powdery mildew and adapted to culture in the Southwest. Pollination and harvesting records and other observations indicated that the inbred lines varied in date of first bloom and in time required for fruit growth. Commercial varieties and foreign plant introductions were also observed to differ in these characters.

Early fruits command premium prices in the markets. Earliness is therefore an important factor in commercial muskmelon culture. The studies reported here were initiated to learn something about the mode of inheritance governing earliness in the muskmelon. The discovery of a gene for male sterility in the muskmelon by Bohn and Whitaker (1949)[4] makes the use of commercial F_1 hybrid muskmelons possible. The present report is a study of earliness as measured by the time to first flower and to first fruit of certain F_1 hybrid muskmelons and their parent varieties.

PLANT MATERIALS

The experimental materials consisted of commercial varieties (not inbred) and first-generation variety hybrids of muskmelons.

Parent Varieties. Nine varieties differing in type and vigor and ranging in time of first harvest from very early to very late were selected as parents. The variety designations used herein refer to the following varieties or breeding lines: (1) *Conomon, Cucumis melo* var. *Conomon* as described by Bailey (1949); (2) 17213M, a mass-increased cantaloupe[5] breeding line; (3)

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[4] See "Literature Cited" for citations, referred to in text by author and date.

[5] The terms muskmelon (all cultivated varieties of the species *Cucumis melo* L.) and cantaloupe (dark-skinned, netted, salmon-fleshed varieties of muskmelons) are used in accord with their usage by Davis, Whitaker, and Bohn (1953).

TABLE 1

GEOMETRIC MEAN NUMBERS OF DAYS FROM PLANTING TO FIRST PISTILLATE FLOWER IN MUSKMELON F_1 HYBRIDS AND THEIR PARENTS GROWN AT BRAWLEY AND DAVIS, CALIFORNIA, 1948

Hybrid number	Cross	Brawley plantings			Davis plantings			All plantings		
	P_1 (early) × P_2 (late)	P_1	F_1	P_2	P_1	F_1	P_2	P_1	F_1	P_2
1	Conomon × PMR No. 5	86	88*[1]	94	51	55	56	70	73	77
2	17213M × PMR No. 5	93	90**	94	55	55	56	75	74**	77
3	PMR No. 5 × Melogold	94	88*	93	56	55**	60	77	73*	78
4	PMR No. 5 × Kelly Sweet	94	94	101	56	56**	65	77	76**	85
5	PMR No. 5 × Honey Dew	94	90*	99	56	59	63	77	76**	82
6	PMR No. 5 × Golden Beauty	94	92**	100	56	62	67	77	79**	86
7	Melogold × PMR No. 7	93	90**	97	60	58	58	78	76*	79
8	PMR No. 7 × Honey Dew	97	91*	99	58	59	63	79	77**	82
9	17213M × V-1 ♀	93	94	99	55	58	61	75	77	81
10	17213M × V-1 ♂	93	94	99	55	57	61	75	77	81
11	Conomon × Golden Beauty	86	92	100	51	58	67	70	77	86

[1] An unmarked hybrid did not differ significantly from the average of its parents; a hybrid marked
* was significantly earlier than its early parent; one marked
** was significantly earlier than the average of its parents.

PMR No. 5, Powdery Mildew Resistant Cantaloupe No. 5 as described by Davis, Whitaker, and Bohn (1953); (4) PMR No. 7, Powdery Mildew Resistant Cantaloupe No. 7 as described by Whitaker and Davis (1946); (5) V-1, Sulfur-resistant V-1 as described by Hoadley (1947); (6) Melogold, the Melogold variety of pink-fleshed honeyball as described by Davis, Whitaker, and Bohn (1953); (7) Honey Dew, the green-fleshed Honey Dew variety as described by the same writers; (8) Kelly Sweet, a finely netted, yellow-green-fleshed muskmelon similar to the Nutmeg variety as described by Tapley, Enzie, and Van Eseltine (1937); and (9) Golden Beauty, the Golden Beauty casaba as described by Davis, Whitaker, and Bohn (1953). The parental combinations of the F_1 hybrids are shown in table 1, column 2, headed P_1 (early) and P_2 (late).

Variety Hybrids. The F_1 hybrid progenies were compared with their nine parental varieties at Brawley and at Davis, California, in 1948.

PLANTING METHODS

Plantings at Brawley. Replicated plantings were made on each of three planting dates at each location. At Brawley the seeds were planted directly in the field in four replications of 10-plant plots on each of three planting dates. The cultural practices were those commonly used in the early spring districts of California according to Davis, Whitaker, and Bohn (1953). Two plants were grown in a hill with 3 feet between hills in beds spaced at 6 feet. The hills in the December 8 and January 5 plantings were covered with paper caps until March 1. The February 2 planting was not covered. The seeds were planted in presoaked beds that were again irrigated after planting to promote rapid germination. Additional water was applied March 1, after danger from frost had passed, and thereafter according to commercial practice in the district. The plants were infected with mosaic viruses transmitted by aphids in mass flights during April, as described by Dickson (1949). Infection was nearly simultaneous in all plants and reached 100 per cent in the field two weeks after the first symptoms were noted. The virus infection slowed growth rates and introduced an unknown amount of bias into the data.

Plantings at Davis. At Davis the seeds for four replications were planted in pots in the greenhouse on each of three dates, May 3, May 19, and June 1. The plants were transplanted to the field when they were three weeks old. Each planting was arranged in randomized blocks in the greenhouse and in the field. Several seeds were planted in each of 10 pots for each field plot. The plants were thinned in the field to a single plant in each of 10 hills in a plot, spaced at 6 feet in rows 6 feet apart. They were fertilized, cultivated, and irrigated according to methods recommended for the Central Valley by Davis, Whitaker, and Bohn (1953).

Variation in Environmental Conditions. The plants in these experiments were subjected to six different sets of environmental conditions that ranged from a December planting for early spring harvest in Imperial Valley to a June 1 planting for fall harvest in the Central Valley. They were exposed to a wider range of environmental conditions than they would have been in single-date plantings at one location during six successive years.

PRELIMINARY STUDY OF GROWTH PERIODS

Fractional Growth Period. In the study of earliness the growth period was partitioned into components similar to those described for tomatoes by Powers and Lyon (1941), Lyon (1941), and Powers and Locke (1950). At Brawley, plot data were recorded on dates of: (1) first staminate flower; (2) first pistillate flower; and (3) first 10 fruits ripe. Preliminary study of the data indicated that whole plot measurements of flowering dates were too inaccurate for critical analysis. Accordingly, individual plant data were recorded at Davis on dates of: (1) first staminate flower; (2) first pistillate flower; (3) first recognizable set fruit; and (4) ripening of the first set fruit. Separate analyses by locations demonstrated very significant differences in all of the fractional periods caused by dates of planting, varieties, and the interaction of varieties X dates of planting.

Effects of Environment and Variety on Growth Period. The potent environmental effects, indicated by the very large date of planting variance in each analysis, supported the work of Hall (1949), Mann and Robinson (1950), and Nitsch, *et al.* (1952). Those authors reported that several environmental factors have potent effects on the flower differentiation rates, sex expression, fruit-setting ability, and fruit-growth rates of several cucurbits. The large variety variance demonstrated that genetic factors, also, had potent effects on the lengths of the fractional growth periods. Varieties that produced very early staminate flowers usually required a long time following staminate flowering for pistillate flower production and for fruit setting, as in the Melogold. Late staminate flowering varieties, such as the Kelly Sweet and Golden Beauty, usually required relatively short times following the first staminate flower for pistillate flower production and/or fruit setting. The Conomon was exceptional; that variety was consistently early in all growth periods.

Two Growth Periods Selected for Study. Information of general interest could be gained from analyses of certain combinations of the ultimate growth periods. For brevity and convenience, the total growth period, or maturity period, was divided into: (1) the juvenile period from planting to first pistillate flower; and (2) the ripening period from first pistillate flower to first ripe fruit. The term "early maturing" is used herein with reference to a variety or hybrid with a short total growth period; the term "early flowering" refers to a variety with a short juvenile period; the term "early ripening," to a variety with a short period from first pistillate flower to first ripe fruit.

ANALYTICAL METHODS

The data on the maturity period and its fractions, juvenile period, and ripening period, were studied by the analysis of variance. Certain hybrids were also compared with their parents by Students' method as stated by Paterson (1939). The great range of environmental conditions caused such extreme variation in plant performance that the original data from all plantings could not be combined in a single analysis of variance for each growth period. Chi-square tests demonstrated that the variances of the different plantings were not homogeneous with one another. The original data were transformed into logarithms to eliminate differences caused by differences in mean size. The variance of the Davis second planting still appeared to be aberrant. That particular planting was severely damaged by insects (elaterid larvae) which were active when the plants were set in the field. Some plots, including those containing the important PMR No. 5 parent and its hybrids with Melogold and 17213M, were completely destroyed and several were severely damaged before the insects were controlled. The insects caused little damage in the first and third plantings. Data from the Davis second planting were not considered further. The logarithmic transformations of the data from the three plantings at Brawley and the first and third plantings at Davis were analyzed separately, by locations, and combined for each growth period.

OBSERVED DIFFERENCES IN GROWTH PERIODS

Juvenile Period

Differences in length of the juvenile period (time required to attain sexual maturity) were measured by number of days from planting to anthesis of the first pistillate[6] flower. The length of the juvenile period varied from 48 days for several F_1 hybrids in the last planting at Davis to 121 days for the Kelly Sweet variety in the first planting at Brawley. The analyses demonstrated very significant differences among the varieties and hybrids in each of the five plantings.

Error Variances. The error variances of the logarithmic transformations of the five plantings exhibited large residual differences that could not be attributed to differences in mean size. Those differences suggest that microenvironmental factors, such as plot position and available moisture, caused more variation in the first and second plantings at Brawley than they did in the other three plantings. Such effects could well be expected in the two covered plantings that were started during the winter. They were watered at planting and again on March 1, in accord with commercial practice. The long periods, 83 and 55 days, respectively, between irrigations permitted the soil to dry considerably. It seems likely that differences in moisture could have caused some of the observed differences in plant development. The other three plantings were not exposed to long periods between irrigations.

Date of Planting and Location Effects. The analysis of the data from all plantings combined permitted the comparison of the relative effects of variety and of dates of planting on plant performance (table 2, C). The variance for dates of planting was 132 times as great as the variance for varieties for the period from planting to first pistillate flower. The large difference indicated that environmental factors, such as temperature and light, were far more important than genetic factors in controlling the length of the juvenile period. The average numbers of days from planting to first pistillate flower for all varieties and hybrids in the five plantings were: December, 109; January, 93; February, 80; May, 65; and June, 52. Plants started during the cold, short days of December at Brawley required more than twice as

[6] Pistillate as used herein indicated any flower with a pistil without regard to the presence or absence of anthers.

long to produce pistillate flowers as did those started during the warm, long days of June at Davis. Increases in earliness of planting did not produce equal net increases in earliness of flower production. Plants started at Brawley during February flowered only 27 days later than those started 56 days before, during December.

Variety Effects. The relatively large variances for varieties (including F_1 hybrids) compared with the varieties X dates of planting interaction vari-

TABLE 2
ANALYSES OF VARIANCE OF LOGARITHMS OF DAYS FROM PLANTING TO FIRST PISTILLATE FLOWER IN MUSKMELON F_1 HYBRIDS AND THEIR PARENTS GROWN AT BRAWLEY AND DAVIS, CALIFORNIA, 1948

Variable	Degrees of freedom	Sum of squares	Variance	F
A. Plantings at Brawley				
Varieties	19	0.088 058	0.004 635	8.55**[1]
Dates of planting	2	0.705 615	0.352 808	650.94**
Varieties X Dates	38	0.031 448	0.000 828	1.53*
Error	177	0.095 917	0.000 542	....
B. Plantings at Davis				
Varieties	19	0.124 048	0.006 529	24.27**
Dates of planting	1	0.386 074	0.386 074	1435.22**
Varieties X Dates	19	0.008 145	0.000 429	1.60
Error	119	0.031 975	0.000 269	....
C. Plantings at both locations				
Varieties	19	0.183 349	0.009 650	22.34**
Dates of planting	4	5.087 453	1.271 863	2944.13**
Varieties X Dates	76	0.068 350	0.000 899	2.08**
Error	296	0.127 892	0.000 432	....

[1] F values marked * were significant at 5 per cent; those marked ** were significant at 1 per cent.

ances and the error variances indicated that most of the varieties and F_1 hybrids performed similarly in all five plantings (table 2, A, B, C). The nine parent varieties could be grouped into five significantly different earliness classes on the basis of their total performances: very-early flowering, Conomon; early flowering, 17213M and PMR No. 5; medium flowering, Melogold and PMR No. 7; late flowering, Sulfur Resistant V-1 and Honey Dew; very-late flowering, Kelly Sweet and Golden Beauty (table 1, columns 9 and 11).

Effects of Variety X Date of Planting Interaction. The relatively small but very significant interaction variance indicated minor shifts of some varieties and hybrids in relation to one another in the different plantings. Such aberrant behavior of some varieties interfered with the determination of which was the earlier parent in some crosses. For example, the Melogold variety was nonsignificantly earlier than the PMR No. 5 in the first and second plantings at Brawley but it was later than the PMR No. 5 in the other three plantings, significantly so in both plantings at Davis. The Melogold performed similarly in comparisons with the PMR No. 7 variety. The performances of the F_1 hybrids from crosses of those varieties were, therefore, compared with both parents in all plantings.

The F_1 Hybrids Compared With Their Parents. Based on their performance in all plantings combined, all of the hybrids were earlier flowering than the averages of their respective parents; seven of them, significantly so (table 1, columns 9, 10, 11). Six of the hybrids were earlier flowering than their respective early parents; two of them, significantly so.

The apparently heterotic hybrids, numbers 3 and 7, were derived from crosses of two closely related cantaloupes with a honeyball. The three parents were essentially alike in length of juvenile period (table 1, columns 9 and 11). Hybrid number 3 was earlier flowering than either parent in each of the five plantings, very significantly so at Brawley and as measured by the combined error variance (table 1, columns 4 and 10). Hybrid number 7 was earlier than each parent in four of five within-planting comparisons, significantly so in total performance. The data furnished strong evidence that those two similar hybrids exhibited heterosis for early pistillate flowering.

The related hybrids, numbers 5 and 8, were derived from crosses of the same two cantaloupe varieties with the Honey Dew variety. The Honey Dew parent was significantly later flowering than the cantaloupe parents. The hybrids numbers 5 and 8 were significantly earlier than their respective early parents at Brawley. However, they were later than their early parents at Davis; one of them, significantly so. They were earlier than their respective early parents in total performance by margins approaching significance. The data suggested that heterosis for early flowering obtained in the cantaloupe X Honey Dew hybrids during winter and early spring but not during summer.

Hybrid number 2 was derived from a cross between two closely related cantaloupes that did not differ significantly from one another in earliness of flowering. It was earlier than either parent in four of the five plantings, but significantly so in only one. Its margin of earliness over the "earlier" parent, 17213M, was too small to be significant at either location. The difference approached significance in the combined calculations. The juvenile period of the hybrid was significantly shorter than the average of its parents. The data suggested but did not prove that heterosis for early flowering obtained in that hybrid, also.

The hybrids numbers 4 and 6 were derived from crosses between the PMR No. 5 cantaloupe with distantly related muskmelons that were very significantly later flowering than the PMR No. 5. The hybrids were significantly earlier than the parental averages and like the early parent in days from planting to pistillate flowering. The genes operating in those hybrids exhibited dominance for short juvenile period.

The hybrids numbers 9 and 10, from reciprocal crosses between two cantaloupe varieties that differed from one another very significantly in time of pistillate flowering, did not differ significantly from the parental average. Similarly, the hybrids numbers 1 and 11, derived from crosses of the very early flowering Conomon variety with a cantaloupe and with the Golden

Beauty casaba variety, did not differ from their respective parental averages. Each of the two last-named hybrids differed very significantly from both of its parents. The four hybrids exhibited no dominance of genes that controlled length of the juvenile period in all of the environments tested.

The performance of the hybrids as a group appeared to differ in the different plantings (table 1). Several of the hybrids were earlier flowering than their respective early parents at Brawley but later flowering at Davis. This was not necessarily a reversal of dominance because it obtained, also, in certain varieties (Melogold, PMR No. 5, Golden Beauty). It can be as readily explained by the hypothesis that different physiological-genetical processes were limiting rates of growth and flower development in the different environments. Varieties and hybrids that possessed different assortments of genes controlling the several processes would then be expected to behave differently in the different environments.

The considerable range in dominance relations indicated that different genes were operating to control length of the juvenile period in the different hybrids. The observed relationships ranged from well-defined heterosis for short juvenile period in the cantaloupe X honeyball hybrids, through dominance in the cantaloupe X casaba hybrid, to no dominance in crosses derived from the Conomon variety. The demonstration of genes that differed in dominance relationships supported the hypothesis that the genes controlling length of juvenile period affected different growth processes.

Ripening Period

The ripening period, including the time required for fruit setting and fruit growth, varied from 38 days for the Conomon variety in the Davis plantings to 84 days for the Melogold and Honey Dew varieties in the Brawley first planting. Very significant differences occurred among the varieties and hybrids in each of the five plantings. As in studies on the juvenile period, residual differences in the error variances of the five plantings indicated that factors other than mean size caused differences in variation among the different plantings.

Variation Caused by Dates of Planting and Location Differences. In the analysis of the combined logarithmic data, the date of planting variance was nearly four times as great as the variety variance for the period from first pistillate flower to first ripe fruit (table 3, C). Although the environmental factors caused more variation than did the genetic factors, they were relatively less important here than in the juvenile period. Separate analyses of the Brawley and Davis data demonstrated that most of the variation caused by dates of planting occurred between Brawley and Davis; comparatively little such variation occurred within locations (table 3, A and B). The averages for number of days for length of the ripening period for all varieties and hybrids in the five plantings were: December, 68; January, 67; February, 64; May, 54; and June, 55. The figures demonstrated that the ripening period, which occurred during comparatively warm weather in all plantings, varied less among the different plantings than did the juvenile period. Relatively little of the increased earliness sought by earlier planting was lost from longer ripening periods for the earlier plantings. That was especially true within locations.

Variation Caused by Variety and Hybrid Differences. The large variety variance compared with the interaction and error variances indicated that most of the varieties and F_1 hybrids performed similarly in all plantings. The nine parent varieties could be grouped into five significantly different classes for length of the ripening period in all five plantings combined: very fast ripening, Conomon; fast ripening, Kelly Sweet; medium ripening, 17213M, V-1 and PMR No. 7; slow ripening, Melogold and PMR No. 5; very slow ripening, Golden Beauty and Honey Dew (table 4, columns 9 and 11).

TABLE 3

ANALYSES OF VARIANCE OF LOGARITHMS OF DATA ON DAYS FROM FIRST PISTILLATE FLOWER TO FIRST RIPE FRUIT IN MUSKMELON F_1 HYBRIDS AND THEIR PARENTS GROWN AT BRAWLEY AND DAVIS, CALIFORNIA, 1948

Variable	Degrees of freedom	Sum of squares	Variance	F
A. Plantings at Brawley				
Varieties	19	0.582 277	0.030 646	23.45**[1]
Dates of planting	2	0.019 571	0.009 786	7.49**
Varieties X Dates	38	0.109 980	0.002 894	2.21**
Error	177	0.231 265	0.001 307	....
B. Plantings at Davis				
Varieties	19	0.457 433	0.024 075	52.68**
Dates of planting	1	0.002 890	0.002 890	6.32*
Varieties X Dates	19	0.042 352	0.002 229	4.88**
Error	119	0.054 344	0.000 457	....
C. All plantings combined				
Varieties	19	0.851 587	0.044 820	46.45**
Dates of planting	4	0.678 107	0.169 527	175.68**
Varieties X Dates	76	0.340 455	0.004 480	4.64**
Error	296	0.285 609	0.000 965	....

[1] F values marked * were significant at 5 per cent; those marked ** were significant at 1 per cent.

Variation Caused by Variety X Date of Planting Interaction. The small but very significant interaction variance indicated minor shifts of certain varieties and hybrids in relation to one another in the different plantings. The Melogold was more variable than other varieties in length of the ripening period as well as the juvenile period. That variety was later than the average of all varieties and hybrids in each of the Brawley plantings but earlier than the average in each of the Davis plantings. Observations on the plants indicated that the Melogold set fruits with difficulty. The apparent differences in length of ripening period in that variety may have resulted largely from differences in length of time from pistillate flowering to fruit setting. In contrast with the Melogold, the V-1 variety was earlier than the average in each planting at Brawley but later than the average at Davis. The Golden Beauty variety apparently ripened much more rapidly in the last planting than in the other four plantings. Such aberrant behavior may have resulted

TABLE 4

MEAN (GEOMETRIC) NUMBER OF DAYS FROM FIRST PISTILLATE FLOWER TO FIRST RIPE FRUIT IN MUSKMELON F_1 HYBRIDS AND THEIR PARENTS GROWN AT BRAWLEY AND DAVIS, CALIFORNIA, 1948

Hybrid number	Cross	Brawley plantings			Davis plantings			All plantings		
	P_1 (early) × P_2 (late)	P_1	F_1	P_2	P_1	F_1	P_2	P_1	F_1	P_2
1	Conomon × PMR No. 5	55	58[1]	68	38	49***	53	48	54	61
2	17213M × PMR No. 5	64	70	68	52	55	53	59	63***	61
3	PMR No. 5 × Melogold	68	72	76	53	55***	48	61	65	63
4	Kelly Sweet × PMR No. 5	54	57	68	49	53	53	52	55	61
5	PMR No. 5 × Honey Dew	68	73	79	53	58	64	61	66	72
6	PMR No. 5 × Golden Beauty	68	76	77	53	73****	60	61	75****	69
7	PMR No. 7 × Melogold	63	65	76	54	53	48	59	60	63
8	PMR No. 7 × Honey Dew	63	69	79	54	57	64	59	64	72
9	17213M × V-1 ♀	64	63	60	52	54	59	59	59	60
10	17213M × V-1 ♂	64	64	60	52	57	59	59	61	60
11	Conomon × Golden Beauty	55	59**	77	38	51***	60	48	56	69

[1] An unmarked hybrid did not differ from the average of its parents; a hybrid marked
** was significantly earlier than the average; one marked
*** was significantly later than the average; one marked
**** was significantly later than its late parent.

from difficulty in judging ripeness of that very late maturing variety during cool fall weather. Unlike the fruits of cantaloupe and honeyball varieties, those of the Golden Beauty and Honey Dew varieties do not abscise at maturity. Ripeness in the Honey Dew could be judged by skin color change and softening of the blossom end. Ripeness of the Golden Beauty was judged by skin color change alone. That character may have responded prematurely during cool fall weather. The F_1 hybrids from crosses of those varieties with cantaloupes produced fruits that "slipped" from the stems at maturity. Those hybrids, like most of the varieties and hybrids, were more easily judged for stage of ripeness and they performed more uniformly in all plantings.

The F_1 Hybrids Compared With Their Parents. Most of the F_1 hybrids were intermediate between their respective parents in length of period from first pistillate flower to first ripe fruit in all plantings. They required significantly longer periods than their respective early parents but they did not differ significantly from the averages of their parents (table 4). A few hybrids, from wide crosses, exhibited different behavior.

The hybrid number 1 was like the average of its parents at Brawley but it was later at Davis (table 4, columns 4 and 7). Individual planting analyses showed that it was significantly faster ripening than its parental average in the first two plantings, but it was significantly slower than the average in the last three plantings. Comparisons with the averages of all varieties and hybrids in the five plantings confirmed differential behavior of the hybrid in the first two as against the last three plantings. The data strongly suggested that the hybrid number 1 exhibited apparent reversal of dominance: genes that favored fast ripening were dominant during cool weather in early spring at Brawley; genes that favored slow ripening were dominant during warm weather at both locations.

The hybrid number 6 was slower than the average of its parents in all five plantings, but significantly so only at Davis. It was significantly later than its late parent at Davis and at both locations combined (table 4, columns 7 and 10). Comparisons with the averages for all varieties and hybrids indicated that the apparent exceptional lateness of that hybrid at Davis resulted from aberrant lateness of the hybrid in the Davis first planting and aberrant earliness of the Golden Beauty parent in the Davis third planting. The hybrid clearly possessed genes that were dominant for slow ripening but it seems less likely that it exhibited heterosis for slow ripening.

The hybrid number 11 was faster ripening than the average of its parents at Brawley but later than the average at Davis (table 4, columns 4 and 7). Individual planting records showed that it was faster ripening than the average of its parents in the first four plantings, but it was significantly slower in the last planting. Comparisons with the averages for all varieties and hybrids showed that the hybrid performed alike in all plantings. Its apparent exceptional behavior in the last planting resulted from aberrant behavior of its Golden Beauty parent in that planting. If that was correct, the amended data constituted strong evidence that the hybrid number 11 possessed genes that were partly dominant for fast ripening.

The genes that controlled length of the ripening period exhibited no dominance in most of the F_1 hybrids. The exceptional hybrids possessed genes that exhibited apparent reversal of dominance, dominance for long ripening period and, possibly, dominance for short ripening period.

Maturity Period

The length of the maturity or total growth period from seed to seed, was measured by the total number of days from planting to the production of ripe fruits. The average lengths of that period failed to equal the lengths of

TABLE 5
ANALYSES OF VARIANCE OF LOGARITHMS OF DAYS FROM PLANTING TO FIRST RIPE FRUIT IN MUSKMELON F_1 HYBRIDS AND THEIR PARENTS GROWN AT BRAWLEY AND DAVIS, CALIFORNIA, 1948

Variable	Degrees of freedom	Sum of squares	Variance	F
A. Plantings at Brawley				
Varieties	19	0.136 032	0.007 160	52.65**[1]
Dates of planting	2	0.311 384	0.155 692	1144.79**
Varieties X Dates	38	0.017 679	0.000 465	3.42**
Error	177	0.024 062	0.000 136	....
B. Plantings at Davis				
Varieties	19	0.203 411	0.010 706	81.11**
Dates of planting	1	0.088 877	0.088 877	673.31**
Varieties X Dates	19	0.006 705	0.000 353	2.67**
Error	119	0.015 701	0.000 132	....
C. Plantings at both locations				
Varieties	19	0.294 859	0.015 518	115.81**
Dates of planting	4	2.568 610	0.642 152	4792.18**
Varieties X Dates	76	0.068 968	0.000 907	6.77**
Error	296	0.039 762	0.000 134	....

[1]F values marked ** were significant at 1 per cent.

the combined juvenile and ripening periods of some varieties and hybrids in the tables because decimals were dropped. The analyses of variance demonstrated very significant variation caused by varieties, dates of planting, and the interaction of varieties X dates of planting (table 5).

Variation Caused by Date of Planting and Location Differences. The extremely large F values for dates of planting demonstrated the very potent effect of environmental factors on the growth rates of all varieties. The greater F value for dates of planting in the combined analysis compared with that at either location indicated that location had a greater effect than did dates within locations (table 5, A, B, C). The period from planting to the production of ripe fruits for each variety was shorter in each successive planting. The average numbers of days for all varieties and hybrids in the three plantings at Brawley, rounded to the nearest whole day, were 177, 160, and 144. The plants grew less rapidly during winter than during early spring so that differences of 28 and 56 days in planting dates caused net differences of only 11 and 23 days in harvest dates. The average first harvest dates for the December 8, January 5, and February 2 plantings were June 3, June 14, and June 26. The plants grew much faster during the late spring and summer at Davis with averages of 120 and 107 days for the first and third plantings, respectively. A 29-day difference in planting dates there resulted in an average difference of 16 days in harvest date. The average first harvest dates for the May 3 and June 1 plantings were August 31 and September 16, respectively. The 70-day difference between the first and last plantings was much greater than the largest variety difference within any planting (46 days) or the largest difference between variety averages from all plantings (37 days). Obviously, environmental effects were greater than genetic effects in determining the length of the life cycle of the muskmelons in the different plantings.

Variation Caused by Variety X Date of Planting Interaction. The comparatively large F values for varieties and for dates of planting and the small F values for the interaction of varieties X dates of planting in the three analyses indicated the general tendency of all varieties and F_1 hybrids to respond alike to the changing environmental conditions, especially within locations. The small but very significant F value for the interaction indicated that a few varieties and hybrids did not follow the general trend. For example, the variety Melogold was significantly later than the average of all varieties and hybrids in the three plantings at Brawley but it was significantly earlier than the average in the Davis third planting. Similarly, the V-1 variety was like the average in the Brawley plantings but significantly later than the average in both plantings at Davis. The hybrid number 8 was earlier than the average in the Brawley first planting but later than the average in the Brawley third planting and in both plantings at Davis. Those cross-differences were very significant.

Smaller, but significant, cross-differences could be found among the varieties and hybrids in the several plantings. The comparison of the PMR No. 5 and Kelly Sweet varieties is of particular interest because their F_1 hybrid exhibited heterosis for earliness (text p. 467). The Kelly Sweet was earlier than the PMR No. 5 in all three plantings at Brawley and very significantly so in the second planting. However, it was significantly later than the PMR No. 5 in each of the plantings at Davis. The differences cancelled one another so that the two varieties did not differ in over-all performance. The PMR No. 7 and Melogold varieties, parents of the other heterotic hybrid, exhibited the same curious behavior. The PMR No. 7 was significantly earlier than the Melogold in the Brawley plantings, like the Melogold in the Davis first planting, and significantly later than that variety in the Davis third planting. Such anomalous behavior suggested that the genetic mechanisms that controlled relative earliness during early spring at Brawley were not identical with the mechanism that controlled relative earliness during summer at Davis.

The various cross-differences mentioned above, and similar ones, reduced over-all differences between variety and hybrid means. They interfered with the comparisons of hybrids with their parents. Such differences illustrated

TABLE 6

MEAN (GEOMETRIC) NUMBER OF DAYS FROM PLANTING TO FIRST RIPE FRUIT IN MUSKMELON F_1 HYBRIDS AND THEIR PARENTS GROWN AT BRAWLEY AND DAVIS, CALIFORNIA, 1948

Hybrid number	Cross	Brawley plantings			Davis plantings			All plantings		
	P_1 (early) × P_2 (late)	P_1	F_1	P_2	P_1	F_1	P_2	P_1	F_1	P_2
1	Conomon × PMR No. 5	142	147**[1]	163	89	104***	110	117	128	139
2	17213M × PMR No. 5	157	160	163	108	110	110	135	138	139
3	PMR No. 5 × Melogold	163	160**	169	110	110	109	139	138**	142
4	Kelly Sweet × PMR No. 5	156	151*	163	115	110	110	138	133*	139
5	PMR No. 5 × Honey Dew	163	163**	178	110	117	127	139	143**	155
6	PMR No. 5 × Golden Beauty	163	170	178	110	135****	127	139	155***	155
7	PMR No. 7 × Melogold	160	157*	169	112	111	109	139	136*	142
8	PMR No. 7 × Honey Dew	160	160**	178	112	116**	127	139	141**	155
9	17213M × V-1 ♀	157	157	160	108	112	119	135	137	142
10	17213M × V-1 ♂	157	159	160	108	114	119	135	139	142
11	Conomon × Golden Beauty	142	151**	178	89	110***	127	117	133**	155

[1] An unmarked hybrid did not differ significantly from the average of its parents; a hybrid marked
* was significantly earlier than its early parent; one marked
** was significantly earlier than the average; one marked
*** was significantly later than the average; one marked
**** was significantly later than its late parent.

that general statements of relative earliness of varieties and hybrids are limited in meaning and may not hold true for all environments.

Variation Caused by Variety and Hybrid Differences. We can consider the relations among the varieties and hybrids with the above-mentioned limitations in mind. The comparatively large variety variance (more than 17 X the varieties X dates of planting interaction) indicated major differences among the varieties and hybrids despite interference from the interaction. The parent varieties could be grouped into five significantly different earliness classes on the basis of their performances in all plantings (table 6, columns 9 and 11): (1) extra early, Conomon; (2) early, 17213M; (3) midseason, PRM No. 5, PMR No. 7 and Kelly Sweet; (4) late, V-1 and Melogold; (5) very late, Honey Dew and Golden Beauty.

The F_1 Hybrids Compared With Their Parents. Nine of the F_1 hybrids were intermediate between their respective parents in length of period from planting to ripe fruit in total performance (table 6, column 10). Four F_1 hybrids were like the parental average. The hybrids numbers 3, 5, 8, and 11 were significantly earlier than the averages of their respective parents; the hybrid number 6 was significantly later than the average of its parents. Only the hybrids numbers 4 and 7 were significantly earlier than their respective early parents.

The hybrids and their parents displayed some curious variations in relative earliness in the several different environmental situations. Anomalous behavior of the PMR No. 5 and Kelly Sweet varieties at the two locations was discussed above. Their F_1 hybrid was significantly earlier than the average of its parents at Brawley but not at Davis (table 6, columns 4 and 7). It was earlier than the Kelly Sweet parent at figures approaching or exceeding the 5 per cent point of significance in each of the five plantings and it was very significantly earlier than that variety in the five plantings combined. The hybrid did not differ significantly from the PMR No. 5 parent in either planting at Davis, but it was very significantly earlier than that variety in the three plantings at Brawley and in the five plantings combined. The comparisons furnished strong evidence that the hybrid number 4 exhibited heterosis for short total growth period.

The evidence for heterosis in the hybrid number 7 was less decisive. The F_1 hybrid was earlier than the PMR No. 7 parent in four of the five plantings but significantly so in only the Brawley second planting. Its advantage over the PMR No. 7 parent at Brawley and in total performance exceeded the 5 per cent point of significance (table 6, columns 3, 4, 9, 10). The hybrid was very significantly earlier than the Melogold parent at Brawley but not at Davis (table 6, columns 4, 5, 7, and 8); in fact it was significantly later than that parent in the third planting at Davis. The several comparisons suggested that the hybrid number 7 exhibited heterosis for earliness during early spring when conditions were unfavorable for growth of muskmelons in general and especially unfavorable for growth of the Melogold variety in particular. The less decisive differences in performance at Davis suggested that potential heterosis for earliness in muskmelons was not expressed under conditions very favorable for muskmelon growth. This observation is in general agreement with findings reported for Drosophila by Wallace (1955).

DISCUSSION

Genetic Effects in the Fractional Growth Periods. The partitioning of the total growth period into the component juvenile and ripening periods facilitated the study of the genetic mechanisms that controlled earliness in muskmelon F_1 hybrids and their parents. The behavior of the muskmelon varieties and hybrids during the long juvenile period contrasted sharply with their behavior during the short ripening period. Environmental factors had gross effects on the length of the juvenile period and comparatively small effects on the length of the ripening period. The genes that controlled length of the juvenile period in several hybrids exhibited either dominance or heterosis for short juvenile period. The genes that controlled the length of the ripening period in most of the hybrids exhibited no dominance; the exceptions exhibited dominance for long ripening period, reversal of dominance, and possibly, dominance for short ripening period.

Genetic Effects in the Total Growth Period. The action of the genes for length of juvenile period combined with the action of those for length of ripening period produced total growth responses similar to the juvenile growth responses in most of the hybrids. The combined gene actions produced curious results with respect to the total growth period in certain hybrids. Genes that produced heterosis for early flowering in the hybrids from cantaloupe X honeyball and cantaloupe X Honey Dew crosses in conjunction with genes that exhibited no dominance for length of the ripening period usually resulted in apparent dominance or partial dominance for short total growth period. They produced heterosis for short total growth period in only the hybrid number 7.

Genes that were dominant for early flowering combined with those dominant for late ripening to result in no apparent dominance for length of total growth period in hybrid number 2. Similarly, genes that were partly dominant for early flowering combined with those producing heterosis for late ripening to produce apparent dominance for long total growth period in hybrid number 6.

Genes that produced dominance for short juvenile period in hybrid number 4 in combination with genes that produced no dominance for length of ripening period resulted in apparent heterosis for short total growth period. That curious result was brought about by the contrasting behavior of the hybrid and of its parents during the different growth periods. The Kelly Sweet parent was very late flowering and early ripening; the PMR No. 5 parent was early flowering and late ripening. Both parents were midseason in total performance. The F_1 hybrid performed like the early flowering PMR No. 5 parent in the juvenile period and it was intermediate between the average and the early ripening Kelly Sweet parent in the ripening period. The resulting total growth period of the F_1 hybrid was very significantly shorter than that of either parent.

Unlike the genes for fruit number and fruit size in tomato discussed by Powers (1944), the genes that controlled early flowering and early ripening in muskmelons were algebraically additive and not geometric in their interaction. The several comparisons suggested that the F_1 hybrid exhibited heterosis caused by dominance and not by overdominance at individual loci. In the absence of unexpected physiological or genetic linkages, true-breeding types earlier maturing than either parent should occur following the combination of genetic factors for early flowering and early ripening in segregating populations.

There was evidence that direct practical advantage through earlier maturity could be gained from the use of F_1 muskmelon hybrids for commercial culture. An F_1 hybrid earlier than either parent was derived from a cross between an early-flowering, slow-ripening variety and a late-flowering, fast-ripening variety. Such a hybrid that also possessed high quality and other requirements for commercial use could be used directly to avoid the long breeding program that would be required to secure early maturity in a true-breeding variety.

It seems possible that the degree of early maturity observed in certain hybrids could also be secured in true-breeding populations. Selection for short juvenile period and short ripening period in inbred lines derived from the apparently heterotic F_1 hybrids should produce homozygous individuals earlier maturing than either parent. A breeder should be able to derive, from such plants, varieties of the several sorts of commercial muskmelons that would ripen earlier than any of those that are now available.

The failure to find beneficial heterosis for early maturity and its fractions early flowering and early ripening in some of the crosses reported herein is in agreement with the findings of earlier workers in California. Rosa (1928) found no deleterious effects from seven generations of inbreeding in the muskmelon varieties Salmon Tint, Hales Best, Honey Dew, Honeyball, and Casaba and no hybrid vigor from crossing inbred lines. Scott (1933) reported data that supported Rosa's conclusions.

The finding of beneficial apparent heterosis for early flowering and/or early maturity in a few hybrids is at variance with the findings of those workers. It is in accord with Munger's (1942) report of heterosis for yield in muskmelons grown in New York. The different results obtained by different workers can be explained partly by the use of different plant materials by different workers. The data of all workers can be explained by the hypothesis that the advantage observed in some F_1 hybrids over either parent results from dominance relations rather than from heterozygosity *per se*.

CONCLUSIONS

1. Date of planting was the most important factor affecting rate of development in muskmelon varieties and hybrids.

2. Varieties exhibited marked differences so that the earliest variety in later plantings matured before the latest variety in plantings started 28 days earlier.

3. Partitioning the total growth period demonstrated that some varieties were early flowering and slow ripening while others were late flowering and fast ripening.

4. F_1 hybrids exhibited responses ranging from no dominance to apparent heterosis for earliness in the total growth period and in the juvenile growth

period. They exhibited responses ranging from no dominance to dominance for slow ripening in the ripening period.

5. Partitioning the total growth period demonstrated that a hybrid (number 4) could exhibit apparent heterosis for early maturity without exhibiting heterosis for either early flowering or early ripening. Such apparent heterosis may have resulted from dominance interactions rather than from heterozygosity.

6. The use of different plant materials and the dominance hypothesis explain the lack of agreement in the observations on heterosis in muskmelons by different workers.

7. It should be possible to produce, from some crosses, true-breeding lines of muskmelons that are earlier maturing than either parent.

8. Since the apparent heterosis for short total-growth period resulted from dominance interactions, it is possible that apparent heterosis for early flowering, i.e., short juvenile period, also resulted from dominance interactions.

9. Additional evidence will be required to demonstrate whether heterosis for earliness unobtainable in pure-breeding lines occurs in the muskmelon, *Cucumis melo* L.

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141

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