at Geneva while fully dormant in Jan., shipped to Winchester and there compared to dormant scions collected locally from 'Golden Delicious'/'Malling Merton 106' trees.

Adult pine voles caught from orchards in the vicinity of Winchester were placed singly in standard laboratory cages with 7 mm stainless steel wire bottoms. Animals were offered water and commercial rat food continuously throughout all experiments. Each cage was fitted with a metal partition to separate the bedding and feeding areas. Burlap strips were provided for bedding. The animal room was kept on a 16-hr day, 8-hr night, 20° ± 2°C, and a relative humidity of 50 ± 10%.

Each singly caged vole represented 1 replicate. Two stems of a rootstock or other candidate were challenged with 2 'Golden Delicious' stems in each of 24 cages (24 replicates). Stems were placed vertically in the cage with the lower part in about 1.5 cm of water. All stems were about 7 mm diam and 15–17 cm long taken from 1-year-old growth. About 13 cm of each stem remained inside the cage. After 24 hr the stem pieces were removed and rated as follows: 0 = no damage; 1 = less than ½ girdled; 2 = ½ girdled or more; 3 = completely girdled; and 4 = cut into at least two pieces. The damage rating of the two stem pieces of each rootstock was averaged and a t-test was performed on each clone vs. 'Golden Delicious'. Paired comparisons between clones were not performed so those listed in Table 1 cannot be compared directly.

Results and Discussion

Since peach scions were not as susceptible to damage as apple scions (3), peach stems provided a useful standard with which to check the various vole lots. In 1975 and 1976, 'Golden Delicious' stems were challenged against 'Golden Delicious' to determine the validity of the test procedure (Table 1). These comparisons resulted in a non-significant t-test at 5% when 'Golden Delicious' were challenged with 'Golden Delicious' and a significant test, 5% or 1%, with 'Glohaven' peach scions.

A Japanese rootstock, *M.* X *sublobata* PI 286613 was rejected by the voles in all 3 years (2 trials were made in 1976). Selections from the cross (Malling 9 × PI 286613) tested in 1975 and 1976 indicated at least 1 clone (70M963-41) was resistant; however, the inconsistent results between the 2 years could not be explained. These trees bore a crop in 1976, but not in 1975 and physiologically they could have been different. The Canadian rootstock, *M.* X *robusta* 'R5', was less consistently rejected in 4 tests; limited testing of 'R5' open-pollinated seedlings was inconclusive. Also, 'Ivory's Double Vigour' showed resistance in 2 of 3 years.

Two prairie crabapples, *M. coronaria* 'Charlotte' and *M. ioensis* 'Hucker No. 1' were attacked but lightly in 1975 and 1976. Two flowering crabs derived from crosses between common apple and Oriental crabs, 'N.Y. 11928' and 'Sissipuk', appeared resistant.

An indication of resistance to pine vole was not detected in 'Virginia Crab' or 'Stayman'.

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Fruit Growth and Development, Ripening, and the Role of Ethylene in the 'Honey Dew' Muskmelon[1]

Harlan K. Pratt, John D. Goeschl[2], and Franklin W. Martin[3]

Department of Vegetable Crops, University of California, Davis, CA 95616

Additional index words. Cucumis melo, flowering, fruit set, firmness, soluble solids, maturation

Abstract. **The muskmelon cultivar Honey Dew (*Cucumis melo* L.) has unique horticultural and physiological characteristics, most notably an unusually long period between attainment of acceptable horticultural maturity and self-ripening in the field. Patterns of flowering, fruit set, fruit growth, solids accumulation, softening, ethylene production, respiration, and variation among individual fruits were studied during several seasons. Internal ethylene concentration may be estimated by the following formula: ppm internal = 3.7 ± 1.2 × rate of production in μl/kg-hr. The act of harvesting had no effect on ethylene production or internal concentration. Full ripening required an internal ethylene concentration of about 3 ppm. Horticultural maturity was attained at 35 to 37 days after anthesis, but self-ripening required about 47 days. Commercial harvests include fruits in this range of ages, so treatment with ethylene is required for uniform ripening and consumer satisfaction.**

The 'Honey Dew' muskmelon (*Cucumis melo* L.) is an old cultivar of high quality with distinctive appearance and flavor and unique horticultural and physiological characteristics. 'Honey Dew' fruits differ from the "cantaloupes" in lack of a well-developed abscission layer until commercially overripe, little or no corky net, higher sugar content, a different pattern of fruit growth, and virtual freedom from market disease unless damaged (usually by chilling). This cultivar is adapted only to areas with long, hot, dry growing seasons; leaf disease has

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[2]Present address: Biosystems Research Division, Department of Industrial Engineering, Texas A&M University, College Station, TX 77843.

[3]Present address: Mayagüez Institute of Tropical Agriculture, Mayagüez, Puerto Rico 00708.

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Table 1. Description of classes used in evaluating 'Honey Dew' melon development and ripening.

Developmental class	Approximate days after anthesis	Class name	Class description
A	10	Very early	Growing rapidly in length, 5-cm long; uniformly light green in color; hard, hairy.
B	20	Early growth	Growing rapidly in length, 10-15 cm long; differentiation between opaque ground color and translucent areas appearing as shades of green; hard; hairy.
C	25	Early immature	Growing slowly in length, rapidly in diameter, 15-20 cm long, translucent green color evenly dispersed in lighter ground color; hard, prickly or hairy.
0	30	Immature	Growing slowly, still undersized, still rough or ribby, not well filled out; ground color still greenish; blossom end still hard; no aroma; no waxy skin coating; skin probably still prickly or hairy; will not ripen regardless of treatment; occasionally harvested commercially by mistake.
1	35	Minimum horticultural maturity but unripe	Well filled out and of normal size; ground color white but with greenish aspect, due to translucent greenish speckles, blossom end hard to firm; no aroma; no waxy skin coating; may feel prickly or hairy; not likely to ripen without ethylene treatment; minimum commercial harvest maturity.
1:2	39	Fully mature	Color definitely white, no more than a trace of translucent green color; blossom end hard to slightly springy; no aroma; very little wax; ethylene treatment essential for uniform ripening of a shipment; good commercial harvest maturity.
2	45	Ripening initiated	Color mainly white; blossom end slightly springy; slight aroma; slightly waxy; minimum eating ripeness; will continue to ripen without ethylene treatment but ethylene treatment will speed ripening; occasionally harvested commercially for local shipment.
3	50	Ripe	Color white to creamy white; blossom end springy to soft; pronounced and typical 'Honey Dew' aroma; waxy coating of skin very evident; ideal eating ripeness.
4	55	Overripe	Color creamy white to pale yellow; blossom end soft; strong aroma; abundance of skin wax; maximum eating ripeness.
5	60	Senescent	Color yellow; melon generally soft; very strong aroma; skin very waxy to greasy; unfit to eat.

prevented successful commercial production in humid areas where early loss of leaves prevents accumulation of sufficient sugar. In California, a minimum of 10% soluble solids is legally required for market, but high quality melons have more.

Muskmelon research literature, including nomenclature, has been reviewed by Pratt (18). Little technical information has been published on the 'Honey Dew'. Rattray (22, 23, 24) reported on chilling injury, recommended storage temp, and fruit ripening with the use of acetylene. Market diseases, including chilling injury, were reviewed by Ramsey and Smith (21) and Wiant (28). Practical advice on handling and ethylene ripening of 'Honey Dews' is available (5, 7, 9, 10, 14, 16, 17, 20). Pratt and Goeschl (19) presented selected data on 'Honey Dew' physiology, including respiration, ethylene production, and ethylene effects, Morris and Mann (15) had shown with a bioassay that the ripe 'Honey Dew' fruit produces ethylene. Masuda and Hayashi (12) compared several dimensions of growth in this cultivar; all followed the same general pattern as that of the equatorial circumference. Rosa (25) and Bianco and Pratt (2) compared carbohydrate changes with other aspects of development in 'Honey Dew' and cantaloupe.

'Honey Dew' fruits are harvested by cutting from the vine and are difficult to choose by appearance alone, for they show little superficial change as they mature in the field. The ground color change is very subtle, and identification of the ground color is further confused by the nature of the skin of the fruit. 'Honey Dew' melons are smooth and the skin shows a fine pattern of translucent and opaque areas, the translucent areas appearing as small flecks in the generally opaque background. According to A. R. Spurr (personal communication), these translucent flecks actually are transparent areas wherein the epidermis of the fruit is in direct contact with underlying cells whose color shows through, whereas the opaque areas are those wherein the eipdermis is separated from the underlying cells by intercellular air spaces. The color of these opaque areas shows the true ground (skin) color of the epidermis; its change in color from greenish to white is an important index of maturity, while the change in color of the translucent areas from green to whitish yellow or yellow is an index of ripening. Difficulty in rapid field selection of uniformly mature fruits led to commercial use of ethylene to initiate ripening in the 1930's (8).

The goals of this study were to determine the time course of various aspects of growth, maturation, and ripening, and to identify possible cause and effect relationships among these processes, especially those which might determine the eating quality of 'Honey Dew' muskmelons. Over several years we have run storage and shipping tests with fruits obtained from local packing sheds. In the course of these and other studies, class descriptions for stages of development, maturation, and ripening were developed (Table 1). The usual stage for good commercial harvest has been score "1," but the best commercial operators are now harvesting at score "1:2." Melons of lower maturity than score "1" will not have the required soluble solids content and will not ripen in response to ethylene treatment. Score "1" fruits are unlikely to ripen without ethylene treatment, even after prolonged storage at a warm temp (20–25°C). Because of this curious behavior, we originally thought this cultivar might be genetically variable with respect to ripening ability. Our first effort was to see if all melons would eventually ripen if left attached to the plant in the field and to check the ripening behavior of melons harvested at various times and matched as well as possible by appearance. Subsequently, a full investigation of flowering and fruit development was undertaken to see if the observed ripening phenomena could be explained on the basis of the true age of individual 'Honey Dew' fruits, since the growth patterns of individual cantaloupe fruits ('PMR-45') are quite uniform, and chronological ages (days after anthesis) provide a satisfactory basis for sampling fruits of different stages of development (13).

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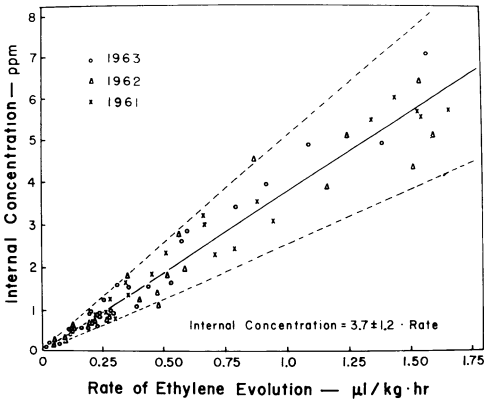

Fig. 1. Relationship between rate of ethylene production and corresponding internal concn in individual 'Honey Dew' melons contained in well-ventilated chambers. The solid line is the calculated linear regression, and the dashed lines are 95% confidence limits.

Materials and Methods

'Honey Dew' melons were grown on the Univ. of California farm at Davis. Seeds were planted at about 3-week intervals beginning about April 15. Spacing was usually 2 to 3 m between rows and 0.3 to 1 m between plants in the row; otherwise the cultural practices of irrigation, fertilization, pest control, and pollination (beehives provided nearby) were typical of well-managed commercial plantings in the area (2, 13).

For most studies, all newly opened perfect flowers were tagged each day for at least 2 weeks after the first flowers appeared in each planting. Flowering usually continued for several weeks, resulting in secondary and tertiary peaks of fruit setting, but these fruits were usually too variable for our purposes. For some purposes, fruitlets were tagged about 7 days after anthesis. About 2 weeks after the cessation of tagging the set fruits were counted. For the most critical experiments, the fruits set during the 3 peak days of a planting were generally used; they were harvested at the desired age by reference to the dated tags and were selected from an even distribution over the field. Growth rates were determined by measuring circumferences of individual fruits at regular intervals, estimating volumes (13), and weighing all harvested samples. Fruits were usually harvested in mid-morning when flesh temperature approximated that of the laboratory (20°C). The fruits were rinsed with tap water, weighed, and the cut stem surfaces dusted with sulfanilamide. The melons were placed individually in respirometers consisting of 25 cm O.D. cylindrical battery jars sealed with bolted lids and rubber gaskets. Air at 9 to 12 liters/hr-kg fresh wt was supplied using calibrated capillary flow meters. The air was not humidified, in order to avoid superficial mold growth, but weight loss was less than 1% in 2 weeks.

The rate of CO_2 evolution was determined by a colorimetric method (4), and ethylene production by means of flame-ionization gas chromatography using an aluminum oxide column (11). In relatively short-term experiments, internal ethylene concn was determined by withdrawing 1.0 ml of air from the placental cavity with a syringe; no wound responses or decay appeared as a result of this procedure. However, for prolonged experiments, internal concn was estimated from the rate of ethylene production determined in the air stream passing over the fruit (3). To calibrate this method of estimation, melons of various ages ranging from 28 days after anthesis (nearly full size) to 55 days after anthesis (fully ripe) were harvested and placed in respirometers at 20°C. At 24 and 48 hr after harvest the rate of ethylene evolution and the concn within each fruit were determined (Fig. 1). The relationship between the internal concn of ethylene and the rate of ethylene production was linear (ppm internal = 3.7 ± 1.2 × rate of production in µl/kg-hr), and this value was used as an empirical constant. Because melons which were 28 days or older were nearly the same size, a correction factor was not necessary for the volume:surface ratio (6). This technique of estimation was also tested by monitoring the internal concn of ethylene in half of the melons in certain experiments and comparing these actual values with the calculated values in the uninjured melons.

The possibility that harvesting *per se* might disrupt the normal rate of ethylene production was tested. Seventeen melons of several ages were covered in the field with small multilayered burlap shelters to insulate them from direct solar radiation, thus preventing sharp gradients or rapid changes in temp. Thermometers were inserted into 5 of the melons at 0800 when the pulp temp averaged about 18°C. By 1300 the pulp temp had risen to 22°C, giving a mean temp of 20°C during the 5 hr period. At this time 1 ml samples of air were drawn from the placental cavities of the 12 remaining shaded fruits and analyzed for ethylene. The same melons were then harvested and placed in respirometers at 20°C. Samples of internal air were again taken 24 and 48 hr after harvest. There was no discontinuity in the trend of internal ethylene concn in these fruits (Fig. 2), and the trends were appropriate for the ages of these melons as established by subsequent studies.

Soluble solids, texture, and dry wt of pericarp tissue were measured in tissue samples obtained by cutting a 5.0 cm wide equatorial slice through the melon and then cutting radially to obtain wedges and cuboid pieces. Soluble solids content of the juice (calibrated as sucrose) was obtained by hand refractometer (1, 26). The % dry wt was obtained by lyophylizing small wedges of tissue. Texture (firmness) was determined with two 5 × 5 cm cuboid slices of pericarp tissue from each melon, placed skin side down in the test cell of an Allo-Kramer Shear Press (Model SP-12 with Model C-15 standard Shear-Compression Test cell and Model R-1 M 3000 lb Electronic Proving Ring) operated at the 300 and 100 lb settings with an 8.9 cm stroke in 30 sec. The numerical value at any point along the resulting recorded peak, when divided by the cross sectional area of the slice, represents the shear compression force. Values of the mean force were calculated from the area under the peak by cutting and weighing the chart paper (sample error was less than 2%).

Results

Flowering and fruit set. The relationship between the no. of flowers opening each day and the percentage of those which set fruit was observed for several years. The first perfect flowers generally appeared about 1 week after the first staminate flowers. The no. of perfect flowers opening per plant increased

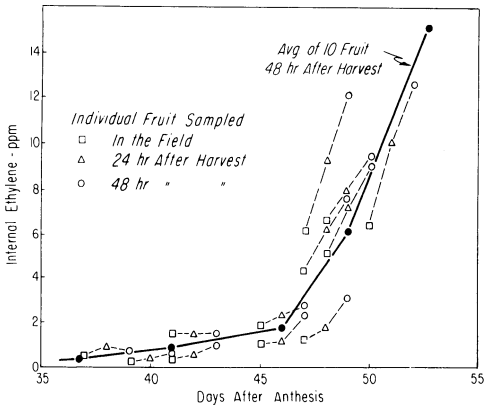

Fig. 2. Preharvest and postharvest internal concn of ethylene in 'Honey Dew' melons of various ages. Each short line represents data from a different individual, the square symbol marking its age at harvest. The continuous curve depicts the mean concn in fruits harvested between 35 and 49 days after anthesis (as in Fig. 8).

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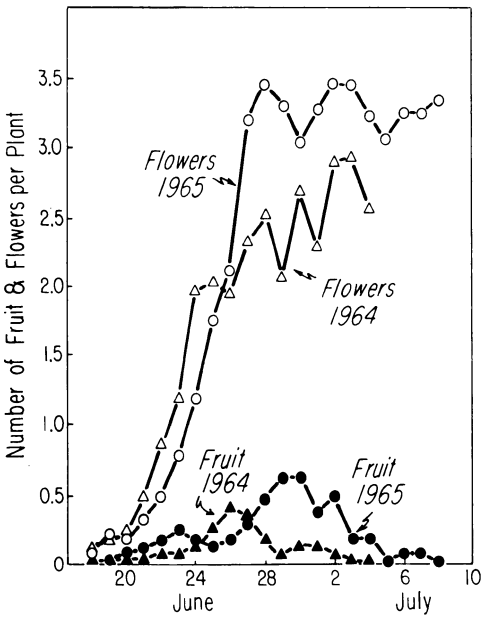

Fig. 3. The no. of perfect flowers which opened each day and the no. of fruits which subsequently set and matured from those flowers in the first plantings of 2 seasons. Tagging of flowers was terminated when the major peaks of fruit setting (the "crown set") were complete.

rapidly for 5 or 6 days (Fig. 3) and then leveled off or increased more gradually for several weeks. Newly formed fruits which were destined to abort stopped growing, lost color, and abscised from the plant within 2 to 7 days after anthesis. While the pattern of flower formation was similar from year to year, the patterns of fruit set varied (Fig. 3, 4, 7). The percentage of those flowers which set fruit usually rose to a peak of about 15% for 3 or 4 days and then declined to near zero, resulting in a "crown set" of about 5 fruits per plant in widely spaced plantings. The percentage of fruit set fluctuated thereafter, leading to varied secondary and tertiary peaks (as in Fig. 4 and 7). These results are comparable to those with cantaloupe (13). Closely spaced plants, as in usual commercial plantings, generally set only 1 or 2 fruits, and the second and third cycles were much reduced or eliminated.

In 3 plantings seeded about 3 weeks apart during 2 different growing seasons, a well-defind peak set occurred in the first planting each year (Fig. 4; see also Fig. 3). Depending upon the weather, flowering and fruit set of the second planting closely followed or overlapped that of the first (Fig. 4A), but peak rate of setting was lower and fewer fruits were produced per plant. Sometimes the rate of set was appreciably lower over extended periods (Fig. 4B). Visual observations of the plantings suggest

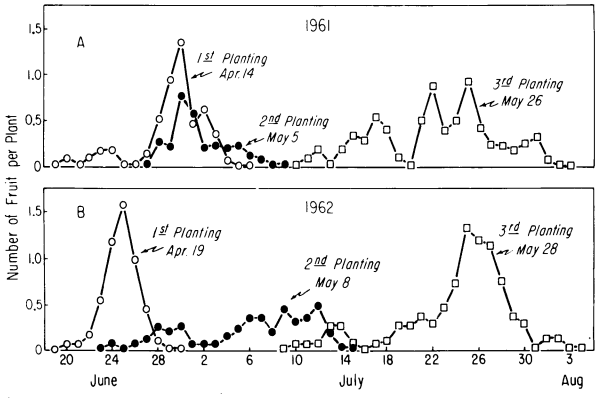

Fig. 4. The no. of melon fruits set per plant each day during the first setting cycle which subsequently grew to maturity in 3 plantings in 2 seasons.

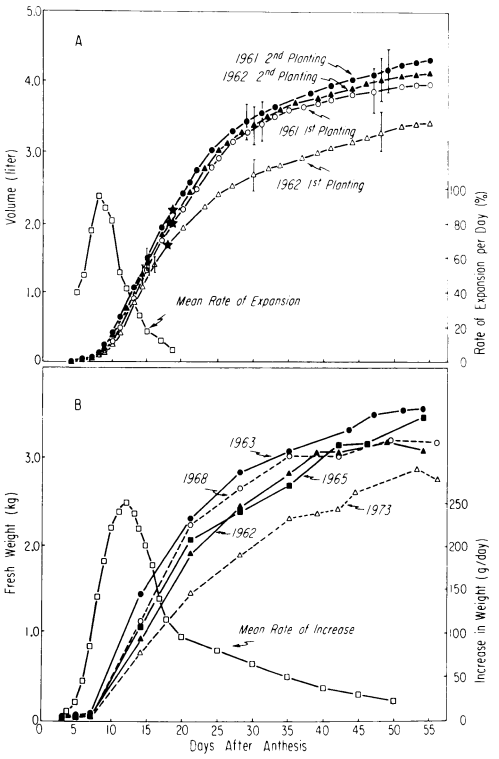

Fig. 5. Growth of melons in volume (A) or fresh wt (B) in various seasons. In 5A, stars show when fruits of the respective groups reached half maximum size, and standard deviations are indicated by vertical lines at 3 points on each growth curve.

that trends in fruit set (Fig. 4) may be related to vine size and leaf area. First plantings have a large total leaf area by the time of flower initiation. Third plantings have a relatively small leaf area when flowering and fruit set are initiated but later achieve larger leaf areas which support the patterns of fruit set. However, these later fruits seldom attain the size of those in the first plantings and, as noted below, not all mature and ripen. Second plantings were often intermediate in behavior with a moderate but steady rate of fruit set.

Fruit growth. Although the absolute rates of growth in volume and final fruit sizes varied, the patterns of growth in different plantings were very consistent (Fig. 5) as indicated by the time required to achieve half the final volumes (Fig. 5A). Curves based on weight (Fig. 5B) closely approximate the volume curves, and mean rates of growth in terms of both volume and weight per day can also be compared (Fig. 5A and B). The apparent density of the fruit (compare liters in Fig. 5A with kilograms in Fig. 5B) decreases as the percentage of the fruit's volume represented by the central cavity increases.

Accumulation of dry wt constituents. During the early, rapid phases of growth the rates of solute uptake, solute incorporation into insoluble products, and cell expansion are apparently balanced, maintaining a relatively constant concn (4.0 ± 0.8%) of soluble solids (compare Fig. 6A and B). After about 20 days, when the fruits have reached half of their final size, another phase of growth begins in which the rate of growth steadily decreases (Fig. 5B), accompanied by a rapid accumulation of solids (Fig. 5A, 6A and B). There are therefore, 2 peaks in the rate of total solids accumulation (Fig. 6B), one coinciding with the most rapid rate of growth (Fig. 5A and B), and the second with the period of rapid accumulation of sugars (Fig. 6). The rate of accumulation and the final concn of soluble solids vary from year to year, but the length of time required for the fruit to reach one-half of the final net increase in soluble solids (Fig. 6A) is relatively constant at about 35 days after anthesis.

Under midsummer growing conditions at Davis, melons

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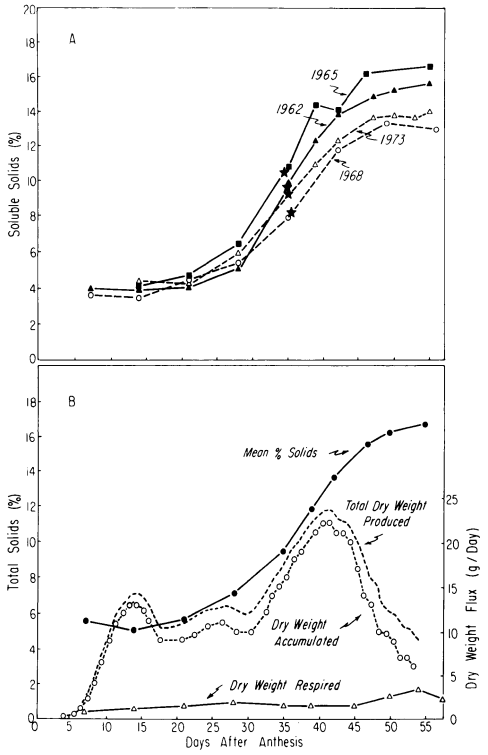

Fig. 6. Soluble solids (A) and mean dry wt (B) during growth and development of melons during several seasons. In A, stars show when half of the final increase in soluble solids was attained, using the 14-day concn as the initial value. In B, the dry wt accumulation is the resultant of rate of total dry wt production less respiration loss.

judged to be good to excellent eating quality usually contained 13 to 17% soluble solids. Mature melons which had accumulated no more than 10 to 12% soluble solids were only fair quality. The differences in eating quality between those fruits which have not accumulated high sugars when vine ripe and those which have the same low sugar content by virtue of earlier harvest have not been studied.

Field ripening. All fruits which set on 50 vines planted on May 4 were observed until all had ripened on the vine or until the vines declined in vigor and died at the end of the season.

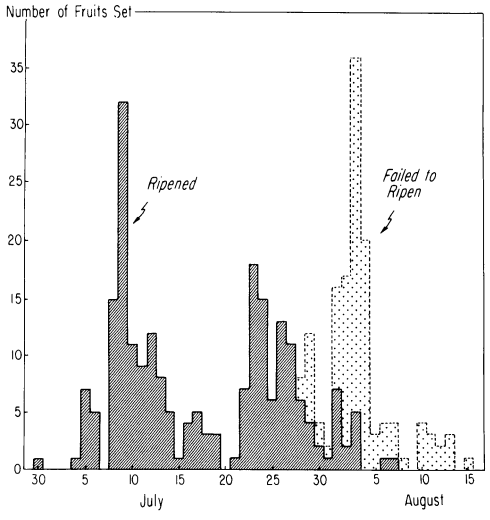

Fig. 7. Total no. of melons set each day on 50 vines from 1 planting during the growing season. Melons represented by dark bars ripened normally in the field. Additional melons represented by light bars failed to ripen satisfactorily.

Table 2. Quality and ripening behavior of 'Honey Dew' melons harvested at various maturity stages and held at 25°C.

Maturity class at harvest[z]	Ethylene treatment (1000 ppm)	Days in storage	Final ripeness score[y]	Soluble solids (%)	No. of melons examined	
					Ripened	Failed to ripen
C	+	49	10.2	4.6	0	8
	–	46	8.2	4.2	0	11
0	+	38	10.7	7.6	0	68
	–	41	9.0	7.5	0	70
0 to 1	+	14	11.5	9.0	29	20
	–	28	11.9	9.6	25	33
1:2	+	4	17.5	11.6	42	0
	–	9	15.8	11.4	37	0
2	+	3	18.0	12.7	12	0
	–	6	16.6	12.8	11	0

[z]See Table 1.

[y]An arbitrary score ranging from 6 (no ripening) to 18 (fully ripe and soft) determined after ripening or at time of discard.

Melons set in 3 distinct cycles with peaks about 12 days apart (Fig. 7). All those set during the first cycle, and most of those set during the second, ripened normally on the vine. However, a few of the second cycle and most of those of the third failed to ripen. Most of these late-set melons did not grow to a satisfactory size, probably due to loss of vigor of the vines near the end of the season; only the first-set fruits would usually be harvested commercially.

Postharvest ripening of fruit samples classified by appearance. To determine whether fruits selected by superficial appearance (as in commercial practice) would ripen off the plant, 15 vines were selected at random each week from the same planting as the vines studied for field ripening (above). All melons over 12.5 cm diam were harvested and classified into development stages (Table 1). The fruits of each stage were further sorted into 2 matched lots which were held at 25°C. One of these lots was treated for 24 hr with 1000 ppm ethylene, approximating a commercial treatment. Thereafter the fruits were examined frequently and scored for ripening. Soluble solids were measured as the fruits ripened or, in the unripened fruits, when the experiment was terminated in late Sept. Harvested melons of high apparent maturity (score "1:2" and "2") ripened readily whether or not they were treated with ethylene (Table 2). Melons of very low maturity ("C" and "O") failed to ripen, although superficial appearance changed somewhat following ethylene treatment (small increase in arbitrary ripeness score). Although ethylene had some effect on appearance in all samples, soluble solids were not affected. Some melons harvested in the "0 to 1" range failed to ripen, even when treated with ethylene; this group fell just below the California legal requirement for average soluble solids content, proving

Table 3. Variation in some characteristics of 'Honey Dew' melons harvested at score "0 to 1" and held at 25°C.[z]

Variable	Avg soluble solids (%)	Avg ripeness score[y]	Avg days to softening or discard
All melons	9.4 ± 1.6	11.7 ± 2.1	25.2 ± 13.8
Melons which ripened	10.1 ± 1.0	11.0 ± 2.4	18.9 ± 3.5
Melons failing to ripen	8.4 ± 1.7	8.1 ± 2.3	33.4 ± 12.7

[z]Melons of Table 2; summation of all "0 to 1" fruits, whether treated with ethylene or not.

[y]See Table 2.

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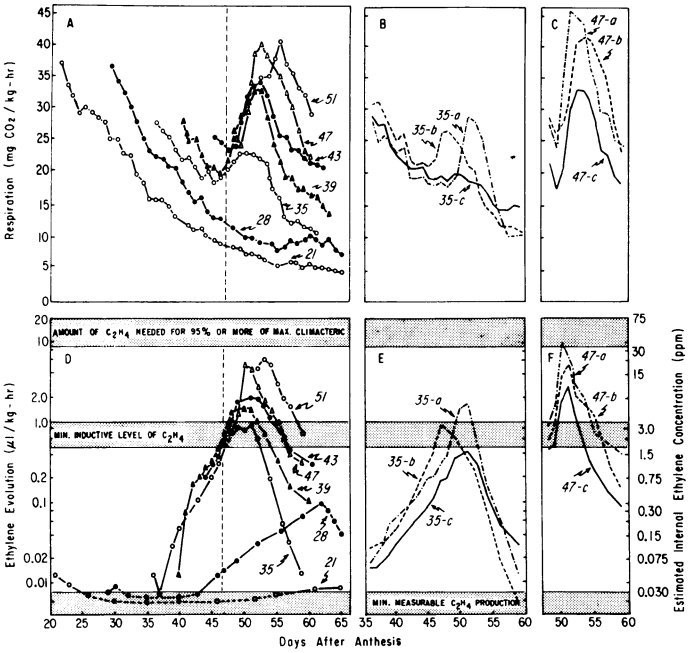

Fig. 8. Mean rates of respiration (A) and ethylene evolution (D) of groups of 10 melons harvested at various ages and studied as individuals. The estimated internal ethylene concn scale corresponds to the observed rate of production. Fig. 8B, C, E, and F show examples of respiration and ethylene evolution patterns in selected individual fruits of the 35- and 47-day groups. Ethylene data are presented on a log scale to show physiologically significant changes more clearly.

the value of this minimum standard. Maturation beyond score "0 to 1" is, therefore, critical for development of a ripening capability in 'Honey Dew' melons, but unfortunately is not accompanied by easily recognizable external changes. Apparently uniform samples evidently contained fruits with a wide range of ages and, therefore, of physiological maturities (Table 3).

Ontogenetic pattern of ethylene production and respiration. Fruits used developed from flowers which reached anthesis between July 8 and July 11, 1963. Samples of 10 melons each were harvested at 7, 14, 21, 28, 35, 39, 43, 47, 51, and 54 days after anthesis. CO_2 evolution and ethylene production were measured daily on each melon until it showed signs of complete senescent breakdown or pathological disorder. The whole family of curves obtained from this experiment was presented by Pratt and Goeschl (19, Fig. 1); selected data are presented herewith (Fig. 8).

The pattern of respiratory behavior (Fig. 8A) of these groups reveals 3 interesting features. First there was a marked post-harvest decline in respiratory activity of young fruit. In the 7- and 14-day fruit (not shown here) this decline was even more striking. The initial portion of this decline may represent a decrease from a higher rate occurring on the plant. Secondly, fruits harvested through 28 days after anthesis did not undergo a significant respiratory climacteric even when stored well past the time of normal ripening. Although ethylene production rose in the 28-day melons, it usually did not reach the minimum required to trigger the climacteric (middle shaded band in Fig. 8D). In melons harvested 35 days after anthesis ethylene production increased continuously (Fig. 8D and E), accompanied by a continuous decline in respiration to the preclimacteric minimum. As ethylene production increased above about 0.6 µl/kg-hr, estimated as the minimum inductive level (19), respiration peaked. The amplitude of the peaks in ethylene production and respiration increased in the older fruits. A third feature of these observations is that the times of the preclimacteric minima and maxima were only slightly affected by the age at harvest, although the amplitude of the climacteric increased in the more mature melons. The 47-day fruits (Fig. 8C) exhibited what is probably a pseudo-preclimacteric minimum representing the usual transient decline in respiration which follows harvest.

By the time of the preclimacteric minimum there had been at least a 20-fold increase in ethylene production as shown by a log plot (Fig. 8D), and by the time of the first statistically significant increase in respiration (marked by the vertical dashed line in Fig. 8A and D) there had been a 100-fold increase in ethylene production (19). The internal concn of ethylene was estimated to be at least 2.8 ± 1.0 ppm at the latter time. The minimum trigger level of ethylene production depicted by the middle shaded band in Fig. 8D would barely have been detected by most analytical methods available before the introduction of gas chromatography, so the 100-fold preclimacteric rise in ethylene production would have been unobserved. The lower shaded band (Fig. 8D) indicates the approximate lower limit of detection with sensitive flame-ionization gas chromatography.

Comparative behavior of individual fruits. The climacteric respiratory patterns shown by individual melons of the same age group varied in time, amplitude, and duration (Fig. 8B and C). Therefore, the mean respiratory behavior of a no. of fruits (roughly equivalent to the behavior of a multifruit sample) shows a broader and lower respiratory peak (Fig. 8A) than that of most individuals. The same is true for patterns of ethylene production (Fig. 8D, E, and F). Hence, respiration and ethylene production are best studied in individual fruits.

In 2 of the 28-day melons there was a noticeable but delayed increase in ethylene production to about 0.6 µl/kg-hr. This increase was accompanied by a small irregular peak of respiratory activity. The remaining 8 fruits were kept until 75 days after anthesis with no sign of a respiratory climacteric. In 2 of the 35-day melons the peak of ethylene production (at the normal time) was lower than the minimum inductive level, and there was no distinct increase in respiration (e.g., melon 35-c, Fig. 8B). The climacteric pattern of the 8 remaining fruits ranged between the amplitude of melons 35-b and 35-a. In this population the 47-day fruits were apparently fully mature, since they ripened to approximately the same eating quality as those left on the plants. All individuals produced sufficient ethylene to induce a climacteric peak of respiration, but there was a considerable range in the magnitudes of these phenomena (Fig. 8C and F). Indeed, many individual melons in the 47- and 51-day groups failed to produce enough ethylene to induce a maximum climacteric rate response (e.g., Fig. 8C and F). In none of the 60 individuals studied over a 3-year period was a climacteric pattern seen if ethylene production was less than 0.42 µl/kg-hr (1.5 ppm internal concentration). The rate was normally between 0.6 and 1.0 µl/kg-hr (3.0 ± 1.0 ppm internally) at the onset of the climacteric. Furthermore there is an obvious correlation between the magnitudes of the ethylene and the climacteric peaks. Our estimate of the ethylene production required for a maximal respiratory response is shown by the upper shaded band of Fig. 8.

Texture changes. Firmness of the pericarp tissue declined sharply beginning about 40 days after anthesis (Fig. 9). This is the earliest response following the upsurge of ethylene production, preceding the induction of the climacteric and other observable aspects of ripening by approximately 7 days. Wang and Mellenthin (27) made a similar observation with 'Anjou' pears.

Discussion

Fig. 9 summarizes important changes and their interrelationships during growth, maturation, and ripening of 'Honey Dew' melons. The data are derived from several seasons, including those presented in detail above. Note that minimal horticultural maturity is attained at 35 to 37 days and a good

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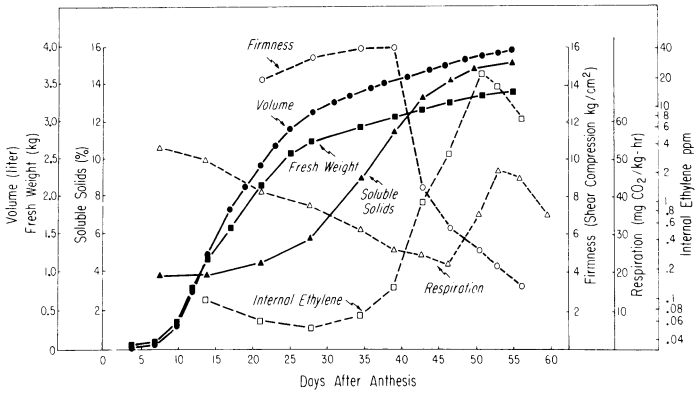

Fig. 9. Changes in growth, soluble solids, ethylene production, respiration, and flesh firmness of 'Honey Dew' melons harvested at different ages. Those values believed to be affected by the endogenous production of ethylene are plotted with open symbols and those not affected by solid symbols.

state of ripeness at about 50 days. The failure of harvested melons to reach an acceptable level of ripeness or quality is clearly not due to an inherent qualitative characteristic of this cv. The field observations of ripening indicated that melons failed to ripen only when maturation was prevented by death or senescence of the vine. Poor ripening response in commercial practice is probably due to physiological immaturity of the harvested fruit. A critical developmental stage occurs during which 'Honey Dew' melons undergo a maturation process unaccompanied by obvious external signs permitting accurate judgment of maturity, so fruits picked in this developmental stage may or may not ripen acceptably. Fruits of this classification that do ripen probably would still be of fairly low quality.

To illustrate these points let us compare 37- and 47-day fruits (Fig. 9). Growth had slowed but the fruits had attained about 87% of their final size by 37 days; soluble solids would have reached the legal minimum of 10% and a score of "1" would be assigned (Table 1), but the fruits would be hard and cucumber-like in flavor. If stored through the normal ripening period, ethylene production would show a minimal peak, resulting in minimal changes in texture, color, or flavor. If treated with ethylene, they would undergo the same degree of softening as a fully mature melon, but there would be no change in sugar content, and some cucumber-like flavor might be retained. On the other hand, 47-day fruit would have 12 to 16% soluble solids, and after storage at room temp for a few days their ethylene production, softening, color, and flavor development would be essentially the same as in those ripening on the vine during the same time span. They might not, however, produce the amount of ethylene required for induction of the maximum respiratory peak rate (19).

Of the phenomena we studied only two, the respiratory climacteric and the reduction in firmness, appear to be directly related to increasing ethylene concn. Conversely, decreasing growth rate and increasing soluble solids are important physiological changes that clearly precede accelerated ethylene production. Since melons do not store starch, ethylene cannot affect soluble solids content by increasing starch hydrolysis as in banana or pear. In our opinion, relatively immature melons harvested at low sugar content (10 to 12%) do not develop the best flavor, even with ethylene treatment. However, the roles of maturity and ethylene production in the development of flavor volatiles in this cultivar remain in question. For example, do the various components of ripening have the same ethylene concn requirements for maximum response as the respiratory climacteric? If they do, then many melons may not reach maximum eating quality in response to endogenous ethylene alone. Ethylene treatment may compensate not only for the range of maturities harvested because of similar superficial appearance but also for an inherent range in ability of mature melons to produce ethylene. Maximal eating quality may require not only that the fruit be fully mature at harvest, but also that it be given a supplemental treatment with ethylene.

Since truly mature melons ripened rapidly and acceptably, commercial quality would be greatly enhanced if the fruit were as mature as possible when harvested, but an ethylene ripening treatment would still provide insurance against sorting errors. Sorting errors are almost inevitable because of the long time span between attainment of horticultural maturity and ripening. However, this time span permits fewer harvests, providing an adequate ethylene treatment is given. Treating the more mature fruits, which would ripen normally anyhow, will cause no harm and assures the uniformity of ripening of a large lot, but ethylene treatment is no substitute for adequate maturity.

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Quality and Condition of 'Delicious' Apples after Storage at 0°C and Display at Warmer Temperatures[1]

R. E. Hardenburg, R. E. Anderson, and E. E. Finney, Jr.[2]
Agricultural Marketing Research Institute, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, MD 20705

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Abstract. **Apples (*Malus domestica* Borkh.) were examined after 0, 2, 4, and 6 months' storage and after simulated retail display for 1 and 2 weeks at 4.4°, 13°, and 21°C. Apples displayed or marketed at 4.4° for 1 week developed less decay and scald than apples held at 21°, and were crisper, brighter, and about 0.55 kg (1.2 lb.) firmer. Apples softened much faster at 21° soon after harvest than after 4 or 6 months' storage at 0°C. The sonic firmness index decreased significantly with both storage time and with increases in display temp. Weight losses from bulk apples during 1 week of display at 4.4°, 13°, and 21° averaged 0.2, 0.4, and 1.8%, respectively. The greatest loss of acidity was also at the warmest display temp. Apples displayed at 13° were of a quality and condition intermediate to those held at 4.4° and 21°. Apples stored in CA for 6 months and then displayed 2 weeks at 21° were firmer and more acid, and had a lower respiration rate than those stored in air. Refrigerated display of 'Delicious' apples is strongly recommended to retard deterioration and preserve their good quality and shelf life.**

Apples are rarely adequately refrigerated in supermarkets. The dessert quality and shelf life of fruit consumers take home are greatly reduced when previous handlers have neglected refrigeration. Many investigators have studied the changes in quality of 'Delicious' apples during storage and ripening (3, 9, 12, 15, 20, 21, 22). Few studies have been done recently to compare various simulated retailing temp on apple quality maintenance. Lewis (13, 14) reported that refrigerated 'Delicious' apples retained an attractive appearance and crisp texture longer than apples held at room temp. Haut (10) and Senn and Scott (19) evaluated post-storage temp for 'Richared Delicious' and concluded that apples should be kept below 10°C if the time between storage and consumption exceeds 6-9 days.

A 1960 study (11) showed that apples displayed under simulated retail refrigeration (10°C) lost less weight and showed less decay than similar apples displayed at room temp. Scald was reduced during marketing when fruit was displayed at 10° or lower (5). Certainly both time and temp are involved in deterioration rate. Mattus et al (16, 17) surveyed the rapidity of sale of apples in Virginia supermarkets. An average of 2.7 days was required to sell 50% of the bulk or loose apples on display and 8.5 days to sell 95%. Only 25% of the bagged apples were in refrigerated displays. Recently a USDA task force studying apple marketing (4) listed many industry problems, including the holding of apples with poor keeping qualities or under poor conditions.

Chain store executives continue to ask for further information on the value of refrigeration for short retailing periods. This research was initiated to determine progressive quality changes of 'Delicious' apples during storage and during 1 and 2 weeks of subsequent display at 4.4°, 13°, and 21°C (40°, 55°, and 70°F). These temp were presumed to represent good, fair and poor retail display conditions, respectively.

Materials and Methods

Fruit source and preparation. The study was conducted in the fall and winter months of 1974-75 in experimental storage rooms at Beltsville, Md. Three lots of 'Delicious' apples were obtained from commercial orchards in Virginia, West Virginia and Pennsylvania within 6 days of harvest. All were size 100 tray packed and graded as Combination U.S. Extra Fancy and Fancy, sports 'Richared', 'Starking', and 'Red Spur' harvested at approx optimum maturity in Sept. Each lot was composited separately and dipped in 2,700 ppm ethoxyquin for scald control. Fruit was then replaced in tray-packed cartons for storage.

Storage and display. Storage was at 0°C with 85-92% relative humidity for 0, 2, 4, and 6 months in air and for 6 months in experimental CA chambers (1% O_2 with <1% CO_2) with and without the ethylene absorbent "Purafil." The initial or 0 storage examination was made when fruit had been at 0°C

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