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Respiration studies of the tomato fruit with reference to the adaptability of this fruit as a subject for further respiration studies.

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RESPIRATION STUDIES OF THE TOMATO FRUIT WITH
REFERENCE TO THE ADAPTABILITY OF THIS FRUIT AS A
SUBJECT FOR FURTHER RESPIRATION STUDIES



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RESPIRATION STUDIES OF THE TOMATO FRUIT WITH
REFERENCE TO THE ADAPTABILITY OF THIS FRUIT AS A
SUBJECT FOR FURTHER RESPIRATION STUDIES

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Thesis submitted for the degree of
Master of Science

University of Massachusetts
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RESPIRATION STUDIES OF THE TOMATO FRUIT WITH
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INTRODUCTION

Although this paper deals predominantly with studies of respiration tendencies of the tomato fruit, these studies are in part correlated with certain past works performed on apple fruits. The purpose of this correlation is to note whether tomato respiratory cycles and responses are sufficiently similar to those of apples to warrant the employment of tomatoes as a substitute material for apples. To better appreciate the desirability for such a substitute, the following explanation is appropriate.

Apples are generally uninfluenced by chemical treatment (except when injury occurs) when they are past the preclimacteric¹ stage of their maturation process (39, 58, 61). Since the preclimacteric phase of an apple exists at the maximum, under normal storage conditions in air, for only a few weeks after harvest, the time when apples are in suitable condition to be responsive to treatments with possible respiratory stimulants or inhibitors is short. A suitable fruit which responds similarly to apples with regard to respiration, and which can be grown in the greenhouse

¹The term "preclimacteric rise" has been assigned to the normal increase in respiration rate of fruit to a respiration peak known as the climacteric point. The rise is followed by a gradual decline as the fruit approaches senescence.

in the late fall, winter, and spring months would give apple storage experimenters a valuable tool with which to work when suitable apples are unavailable.

This paper is, however, not entirely devoted to the problem of denoting apple-tomato respiratory similarities. Data regarding tomato respiratory responses to certain chemical and mechanical treatments have also been included, the main purpose of which is to add significant knowledge to the heretofore lightly investigated topic of tomato respiration.

²REVIEW OF LITERATURE (Tomatoes)

(A) Investigations of Normal, Untreated Tomato Fruits.

Gustafson (26), calculating the respiratory trend of individual, detached, mature-green tomato fruits, found that there occurred, for the first few days, an increase in the carbon dioxide production by the fruits, after which period a slow steady decline in carbon dioxide output occurred. Gustafson commented that these results show tomato fruits to have a respiration cycle similar to that of apples.

Glendenning (15) found, by charting the initial respiration rates of tomatoes picked at various stages of maturity, that a rise in respiration occurred up to that

²The processes of fruit maturation and color development are generally conceded to be closely linked with that of respiration, and are for the purposes of this review considered to be a direct indication of the respiratory trend of the fruit.

point where the fruit was yellow-orange in color, and that this rise was followed by a decline as the fruit ripened to full maturity. In further experimentation involving the continuous measurements of the respiration rates of individual tomato fruits, the same results were obtained. It was also shown that the act of detachment of the fruit from the plant did not interfere with the respiratory sequence which would have been exhibited by the fruit, had it remained on the plant.

(B) Investigations of Tomato Fruits Subjected to Chemical Treatments (Ethylene, Propylene, Methyl-Bromide, 2,4-Dichlorophenoxyacetic Acid, Ethyl Alcohol, Oxygen and Carbon Dioxide).

Studies regarding the effect of ethylene gas on tomato fruits invariably show that stimulation of the metabolic processes of the fruit occurs. It was found by Rosa (54) that ethylene gas at a concentration of 1 part gas to 4300 parts air greatly enhanced coloring and ripening of the treated fruits. Hibbard (34) noted that ethylene definitely reduced the maturation time of June Pink tomatoes. Advancement of maturity of from four to five days due to the gas treatment was recorded by Work (72). Nesterova (47) found that pure ethylene ripened tomatoes eleven days earlier than untreated checks. Hall (27) cited the use of ethylene in the commercial field as a tomato ripening agent.

The work of Furlong (23) seems to indicate that the

stimulating effect of ethylene does not always operate with uniform success on tomatoes. A 0.1 percent concentration of ethylene in the air did not, on the whole, accelerate the ripening of mature-green tomatoes, but mainly increased the ripening of a comparatively few of the slowest ripening fruits. Chace and Church (12), too, encountered difficulty when they attempted to hasten ripening of very immature fruits with ethylene. These men noted better success when the fruit was allowed to mature on the vine to a more advanced stage before exposure to treatment.

What work has been completed regarding the treatment of tomato fruits with propylene tends to point to the fact that this chemical has a greater stimulating power than ethylene. Rosa (55) found that at a concentration of 1 part propylene to 5000 parts of air ripened tomato fruits more rapidly than did ethylene.

Controversy seems to exist concerning the exact effects of methyl-bromide on the tomato respiratory sequence. Jones (36), working in Hawaii, found that exposure of tomato fruits to a moderate dose of methyl-bromide led to a delay of from three to six days in the development of the fruits. Challenging results were advanced by Knott and Claypool (37). These two men noted the respiratory trends of different lots of green tomato fruits which were exposed for a period of twenty four hours to concentrations of the gas ranging from

below, at, and above that concentration recommended for normal fumigation purposes. It was found in this experiment that methyl-bromide had a general stimulating effect, there being, in most cases, fewer ripe fruits in the control lots than in the treated lots.

Mixtures of 2,4-dichlorophenoxyacetic acid (2,4-D) in solution with Carbowax were found by Mitchell and Marth (44) to have no noticeable effect on the rate of tomato respiration.

Injections of undetached, green developing, tomato fruits with different concentrations of ethyl alcohol by Soldatenkov and Kubli (63) accelerated ripening of the test fruits to a marked degree. Ethyl alcohol vapors were also tested and found to contain stimulatory properties although the effects from these vapors were not so marked as the effects resulting from the injection treatment. Nesterova (47) found that ethyl alcohol injections were much less effective than ethylene, but that fair stimulation could be obtained under laboratory conditions.

Soldatenkov (64) found that respiration of tomato fruits was 50 to 100 percent more intense when subjected to high concentrations of oxygen than when subjected to air. Gustafson (25) found that decreasing the oxygen concentration of the atmosphere and at the same time increasing the carbon dioxide content caused a marked reduction in the amount

of carbon dioxide given off by tomato fruits. Rosa (54) found that speed of red color development in the tomato varied directly with the oxygen concentration of the fruit environment.

(C) Investigations of Wax Treated Tomato Fruits.

The respiratory behavior of tomatoes when coated with wax-like compounds has received a notable amount of attention in the recent past. Brown (10) found that coating the fruit with paraffin materially delayed the formation of red color in the fruit. Brooks (7) noted that waxing the skin of the tomato but not the stem scar caused no increase in the carbon dioxide content of the internal atmosphere of the fruit, and that no delay in fruit ripening was evidenced. Waxing the scar but not the skin, however, resulted in a very decided increase in the internal carbon dioxide content, and the delay in ripening and red color formation of the fruit was equal to that ordinarily imposed on the fruit by a 20 degree drop in temperature. Thus Brooks concluded that gaseous exchange between the tomato and the outside atmosphere occurs in the vicinity of the fruit scar, the skin of the fruit being highly impervious to the passage of gases, and that the prevention of gaseous exchange by a barrier such as wax in turn materially retards the rate at which the fruit colors, ripens, and respire. These results are in harmony with work done by Clendenning (15) in which he removed the

calyx parts of attached fruits and applied wax over the resulting scars. Marked inhibition of fruit respiration and ripening rate resulted. This same investigator in a later paper (16) narrowed down the area in which the gaseous exchange occurs in the tomato, stating that this area is localized in a ring of lenticel tissue and is covered by the calyx.

Walford (71) observed two physiological types of tomatoes when fruits, picked at the mature-green stage, were waxed over at the stem scar area and stored at 12.5° C. The fruits of late spring and summer showed a distinct rise in respiration rate as they ripened in storage, while the late autumn and winter fruits exhibited slow and uneven coloring without an attendant rise in carbon dioxide output. He designated these contrasting types as "conventional" and "anomalous", respectively, and provisionally concluded that their distribution was related to seasonal factors.

This occurrence of different physiological types of tomato fruits was later thoroughly investigated by Clendenning (14), who discovered that only waxed fruits appeared in the "anomalous" category, and that when the seals of the "anomalous" fruits were removed, the fruits immediately recovered their "conventional" characteristics. Also, a "conventional" type fruit could be converted to an "anomalous" type simply by sealing over the calyx end of the fruit. Thus it would appear that the "anomalous" type owes its characteristics to

the presence of the wax seal since removal of the wax causes immediate disappearance of the "anomalous" traits, and re-application of the wax causes them to appear once more.

REVIEW OF LITERATURE (Apples)

To the author's knowledge no work has been accomplished which compares tomato fruit respiratory trends and cycles with those of apple fruits. It is for this reason that a presentation of literature relative to this subject is impossible. However, some past respiration work with apples, although having been performed independent of certain previously mentioned tomato fruit experiments, is quite similar in nature and is listed below.

(A) Investigations of Normal, Untreated Apple Fruits.

Krotkov (42) and also Phillips (51, 52) have studied the respiration trends of normal untreated apples during the entire ontogeny of the fruit. Both workers are in agreement that a characteristic rise and fall in carbon dioxide output of the fruit occurs during the senescent period of apples. Further corroboration of the existence of this hump in the respiration cycle of apples is offered by Kidd and West (41), Smock (58), Burroughs (11), Harding (31), Blackman and Parija (5) and others.

(B) Investigations of Apple Fruits Subjected to Chemical Treatments (Ethylene, Methyl-Bromide, 2,4-Dichlorophenoxyacetic Acid, Oxygen and Carbon Dioxide).

Allen (3) noted that a concentration of 1 part of ethylene gas to 1000 parts of air hastened maturity of test apples over those which were untreated. Kidd and West (39) also confirmed the stimulatory effects of ethylene upon respiration activities of apples, and in addition observed that the gas apparently acts in a cumulative manner. It was found that Strumer Pippin apples exhibited stimulation with recovery when first subjected to limited exposures (1 to 5 hours) of ethylene, but longer treatments (1 to 2 days) resulted in loss of recovery by the fruit.

In an effort to determine the feasibility of using methyl-bromide as a fumigant for apple storages, Southwick (67) noted that this chemical appeared to enhance the respiration rate of apples.

The chemical 2,4-dichlorophenoxyacetic acid in mixture with Carbowax was found by Mitchell and Marth (44) to stimulate ripening of Yellow Newtown, Grimes Golden and Rome Beauty apples. Smock and Gross (56) also found notable stimulation of respiration of apples treated with the same combination of chemicals.

It is generally conceded that either a low oxygen concentration or a high carbon dioxide concentration of the atmosphere surrounding apple fruits retards the respiration of such fruit. Eaves (21) reported that low (6.2%) and high (53.5%) concentrations of carbon dioxide stimulated

and depressed respectively the total carbon dioxide output of the apples tested. Magness and Diehl (43) stated that increasing the concentration of carbon dioxide of the apple environment resulted in a slower rate of ripening of the apples. Smock (58) reported that accumulations of carbon dioxide resulting from respiration tend to slow down the respiratory processes of apples. Van Doren (70) exposed apples to various levels of carbon dioxide concentration and found respiration of apples to decrease with increases of the carbon dioxide concentration. Brooks, Cooley, and Fisher (6) also found carbon dioxide in relatively high concentrations to have an inhibiting effect on apples.

Hill (35) showed that inhibition of respiration of fruit tissue resulted from a low oxygen content of the atmosphere. Allen (4) found with apples that in each case where the oxygen content of the environment was reduced, the fruits were materially more firm and of less color than those held in air. Kidd and West (38) also reported the retarding effect on the speed of apple ripening caused by a reduction of the atmospheric oxygen concentration.

The specific effects of varying the concentration of these two gases on fruit respiration are used to good advantage in the modern "controlled atmosphere" storage (1, 2, 40, 60).

(C) Investigations of Wax Treated Apple Fruits.

The resultant effects of wax treatments upon respiration of the apple fruit have been studied, and it has been noted by Smock (58, 59) that this treatment significantly retarded respiration and ripening of apples. The degree of retardation imposed was found to be directly linked with the concentration of the wax used. Magness and Diehl (43) also found that respiration of apples was markedly reduced by coatings of paraffin.

High Points of the Literature Review

It will be noted from the past discussion that apple and tomato fruits are similar in the respect that (a) both types of fruits display a characteristic rise and fall in respiration rate during the senescent period of their maturation process (b) the respiration activities of both types of fruits are stimulated by ethylene treatments (c) a depression of metabolic activities is evidenced by both fruits when subjected to relatively high concentrations of carbon dioxide, low concentrations of oxygen, or when coated with a wax compound.

The respiratory processes of apples are stimulated by methyl-bromide, but the exact reaction of tomatoes to this chemical remains a subject of controversy.

The two fruits react differently to treatments of 2,4-dichlorophenoxyacetic acid, apples being stimulated by exposures to this chemical, while tomatoes manifest no significant response to this treatment.

Tomato fruit respiration can be enhanced by treatment of the fruits with propylene or ethyl alcohol.

METHODS - MATERIALS - APPARATUS

The experimental data which follow are presented in two sections. Section "A" embodies those investigations which deal with the solving of apple-tomato respiratory similarities. Points studied under this heading are (a) stage of maturity at which the climacteric in the tomato occurs (b) the respiratory trends of pre and post-climacteric tomato fruits (c) the effect of ripe apple vapors on the respiration rate of tomatoes (d) the effect of 2,4-dichlorophenoxyacetic acid on the respiration rate of tomatoes (e) the effect of the methyl ester of naphthaleneacetic acid on the respiration rate of tomatoes (f) the stages of maturity at which the tomato fruit is responsive to treatment (g) how all these results compare with the results of similar studies performed on apples by other workers.

Section "B" is composed of experiments which were executed with no regard for apple respiratory tendencies, but which were instead initiated for the purpose of uncovering basic facts concerning the respiration of the tomato fruit. Subjects investigated include (a) the effect of Geon 31X and certain Geon 31X mixtures on tomato fruit respiration (b) the effects of certain wax treatments on the

respiration of tomato fruit (c) the effect of ripe tomato vapors on the respiration of other responsive tomatoes (d) determination of the presence or absence of a stimulating or inhibiting agent in the volatile emanations of tomato fruits.

Materials:

Subjects for the various respiration tests which follow were tomatoes (*Lycopersicon esculentum* Mill.), the variety Comet. The fruits used for the fall set of experiments were procured from greenhouses located at the University of Massachusetts. Fruits for the later spring experiments were obtained from a commercial grower who was located within a few miles of the university. In both cases the fruits were grown at an average temperature of 65° F., and were harvested throughout the season in lots commensurate with the demands of the experiments.

The tomato plants used as indicators for the detection of ethylene among ripe fruit emanations were also grown in the university greenhouses, and were also the variety Comet.

Classification of the Fruit as to Maturity:

The problem of determining ripeness or maturity of tomatoes has received attention in the past, but is still without definite solution (9, 13, 34, 69, 72). The difficulty arises from the fact that the chronological age of the tomato fruit cannot be taken as a measure of the stage of maturity

of that fruit. Often two fruits of identical chronological age are wholly unidentical with regard to physiological age (26). Thus, it is evident that such methods as tagging and noting the date of set of a young tomato blossom could not be used in this set of experiments as an index of the maturity of the resulting fruit. Therefore, it was decided to employ colorimetric means to group together fruits of like or identical maturity.

The tomatoes were separated into five classes with respect to the amount of red color which was displayed by the individual fruit. Colored photographs of these classes were then taken, and may be found on page 17. This record of the established fruit maturity classes or stages was then used as a guide for all classification work done throughout the course of experiments.

Stage #1 corresponds to the mature-green stage of the fruit. Each succeeding stage thereafter represents an advancement in fruit maturity as manifested by an increase in red color of the tomato. Stage #5 represents the fully mature, deep red fruit.

Apparatus:

The diagram on page 18 is a picture of the equipment employed in the experiments which follow to determine the rate of carbon dioxide liberated by the test fruits over a

given period of time in the process of respiration. A volume of air, the passage of which is facilitated by a mercury pump, is drawn through a solution of sodium hydroxide (H) and is, in the process, washed clean of all carbon dioxide. The carbon dioxide free air is then humidified (G) and directed to the respiration chamber (D) which is immersed in a water bath (F) held at a temperature of 74° F. Enroute to the chamber the temperature of the air is modified to conform with that of the water bath by means of passage through submerged copper tubing. Carbon dioxide, emanating from the test fruit (E) contained within the respiration chamber, is picked up by the passing air current after which the mixture is transported to the absorption tower (A). Here the carbon dioxide laden air is broken into small bubbles by means of a sintered glass disc (B), and is absorbed by a measured quantity of sodium hydroxide (50 ml. of approximately 0.5 N) (C). After the determination is completed the sodium hydroxide is drained from the towers (A). The towers are rinsed several times with distilled water which collects in the 500 ml. volumetric flasks beneath. Barium chloride is added to the solution to precipitate the carbonates and additional water is added until each volumetric flask contains exactly 500 ml. of solution. An aliquot of the excess base is titrated against standard hydrochloric acid, using phenolphthalein as an indicator, and the milligrams of carbon dioxide per kilogram of fruit per hour is calculated.

It was found in the beginning phases of this work

that the rate of air flow, within limits, governed the magnitude of the final carbon dioxide reading. A rate less than 0.01 cubic feet per minute proportionately reduced the value of the ultimate results, while a flow above this critical level (0.01 to 0.03 cubic feet per minute) had little or no effect upon the final results. Thus, care was taken throughout the experiments to maintain a flow of air well above this threshold level.

The apparatus used for the detection of the active ingredient (ethylene) by the epinastic responses of indicator plants is diagrammed on page 19. A column of air is first humidified (C) and is then passed through the chamber containing the test fruit (B). Here it picks up the emanations of the fruit, and then passes on to the chamber containing the indicator plant (A).

Handling of the Test Fruit:

The tomatoes were transported to the laboratory immediately upon being picked. There, with as little delay as possible, they were assigned to one of the five established maturity classes. Next, the fruits in each class were divided into lots consisting of about twelve fruits and weighing in the neighborhood of 1500 grams. Each lot was then subjected to the treatment demanded by the terms of the particular experiment in which it was to be used, and placed in the respiration machine, there to remain approximately 24



Stage # 1.



Stage # 2.



Stage # 3.



Stage # 4.



Stage # 5.

Figure 1. Stages of tomato maturity based on fruit color.

Respiration Apparatus

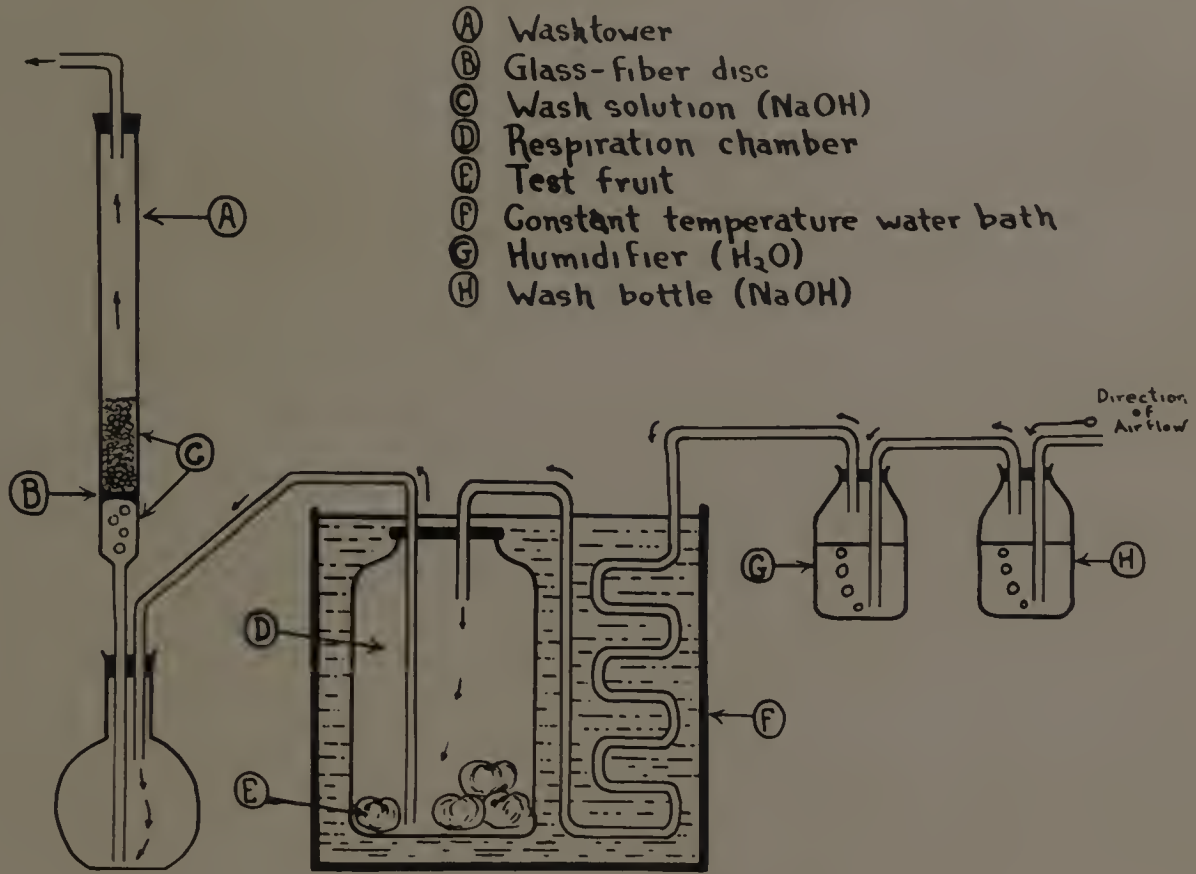


Figure 2.

Epinasty Apparatus

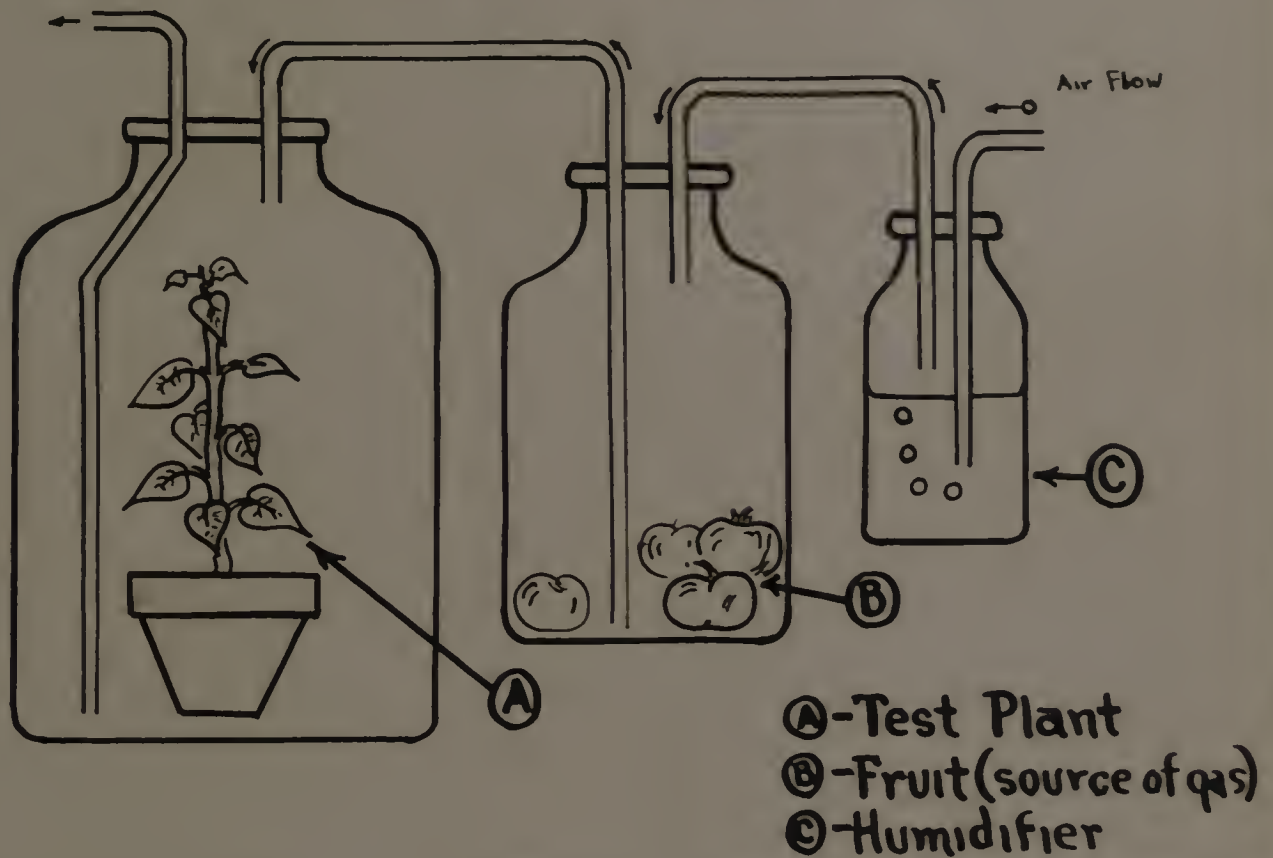


Figure 3.

hours before the first quantitative carbon dioxide reading was taken. Readings of from two to three hours duration were taken daily thereafter, until the study of that particular lot was completed.

The rate of fruit color change is an excellent indicator of the speed at which the fruit ripens, and thus also the speed at which the fruit passes through its respiratory cycle. Therefore, records of color changes of the test fruits were taken at strategic intervals during the course of the experiments, and are presented in tabular form following the graphical presentation of the respiration data for the same fruits.

PRESENTATION OF EXPERIMENTAL DATA

PART "A"

Experiment # 1. Respiration Studies of Untreated Tomato Fruits.

During the months of October and November of 1948 various lots of tomatoes corresponding to the stages of maturity from #1 to #5 were harvested, and the respiration curves for the untreated fruits obtained. The results of this study are graphically portrayed on page 26.

The mature-green tomatoes classified as Stage #1 showed an initial rise in respiration rate lasting for about six days until a peak or climacteric point was reached.

Following the climacteric, the production of carbon dioxide by the fruit manifested a gradual but steady decline.

The fruits of Stages #2 through #5, without exception, responded similarly to one another in that they all showed an immediate and continuous downward trend in respiration rate.

Experiment # 2. The Effect of Apple Vapors on Tomato Fruit Respiration.

Twin batches of tomatoes of Stages #1 through #3 were harvested in November of 1948 and placed in the respiration apparatus. Jars containing about 1500 grams of ripe apples were attached to certain air intake ends of the respiration machine so that the gaseous emanations of the apples were passed over one of the twin sets of tomato fruits. The second set of test fruits remained untreated and acted as a check. Respiration rates were recorded as well as fruit color changes, the results being included on pages 27 and 28.

It was noted that the treated lots corresponding to Stage #1 manifested a much greater initial production of carbon dioxide than did the check lots of the same maturity. The climacteric of the treated fruits of this stage not only occurred at a higher plane, but also occurred at an earlier date than did the climacteric of similar check fruits.

It seems from this bit of evidence that apple vapors quite definitely stimulate the respiratory activities

of mature-green, preclimacteric tomatoes. Further evidence in support of this point may be gleaned from a comparison of fruit colors taken at approximately the mid-point of the experiment (Fig. 5). Here it was observed that the treated fruits were, as a whole, much more advanced in maturity than were the untreated check fruits.

A study of the respiration curves of treated and untreated fruits of Stages #2 and #3 shows no significant differences between these two sets of fruits. Both sets of maturities were uninfluenced by the vapors of ripe apples, and similarly showed an immediate and constant downward path in respiration intensity. A review of the color recordings (Figs. 7 and 8) shows that the treated and untreated fruits matured at approximately identical rates, and substantiates the view that postclimacteric tomatoes are unresponsive to ripe apple vapors with regard to respiration and to red color development.

Experiment # 3. The Effect of 2,4-Dichlorophenoxyacetic Acid (2,4-D) on Tomato Fruit Respiration.

Because it appeared in the last experiment that postclimacteric tomatoes were immune to stimulatory treatment which affected preclimacteric fruit, it was decided to use only preclimacteric tomatoes in the studies which follow. Thus, to test the effects of 2,4-D on the respiratory processes of tomatoes, only Stage #1 fruits were subjected to

a 1000 p.p.m. concentration of the chemical. The test fruits were harvested in November and again in December of 1946, whereupon they were exposed to the treatment applied by means of a hand sprayer, and placed in the respiratory machine for study. Duplicate, untreated lots of fruit were used as checks. Results are shown on pages 29 and 30.

Check and treated fruits reacted in approximately like manner with relation to respiration rate. A study of the fruit color changes of the first test indicates little variation in the rate of maturation between treated and untreated lots. The check fruits of the second test did color and mature slightly ahead of the treated specimens, but the extent of this difference is perhaps of negligible proportion, and is not corroborated by the respiratory findings of this same test.

Apparently 2,4-D, at the strength used in this set of experiments had little or no effect on the respiratory tendencies of unripe tomato fruits.

Experiment #4. The Effect of the Methyl Ester of Naphthaleneacetic Acid on Tomato Fruit Respiration.

Experiments involving the use of the methyl ester of naphthaleneacetic acid were conducted in November and December of 1946 as well as in April of 1940. As in previous tests, only State #1 fruits were harvested, and these were

immediately exposed to a 1000 p.p.m. concentration of the chemical. This material was applied to the fruit by means of a hand atomizer. Respiration and color change studies of these as well as duplicate lots of untreated check fruits were made, the results of which are published on pages 31 and 32.

The respiration curves of the November and December test fruits treated with a 1000 p.p.m. mixture suggest that stimulation did occur. The carbon dioxide emanations of these treated fruits were noticeably greater in the beginning portions of the test than were those of the checks. An average of the color data of the two test lots shows them to have been of a more mature nature than the checks by the date of the last color reading. Thus, the color record agrees with the respiration findings by indicating that stimulation had occurred.

Fruits of the same season as those just described, treated with a 2000 p.p.m. strength of the chemical, also gave indication of respiratory stimulation during the first few days of the test. The color findings for this specific test are, however, of a contradictory nature. They show that the check fruits were actually of a more advanced degree of development by the time of the second color reading than were the treated specimens. The exact cause of this disagreement of results is not understood.

Whereas the 1000 p.p.m. and the 2000 p.p.m. treatments of the methyl ester of naphthaleneacetic acid generally

stimulated the respiration rate of the November and December fruits, no such results were forthcoming when the same treatments were applied to fruits harvested in April. The respiration curves in this latter case show inhibition to have occurred. The corresponding color data are difficult to evaluate due to an extreme lack of uniformity of ripening (red color development) between the individual fruits used in the test. Of the checks, some fruits had reached full maturity while, at the same time, others of the same lot failed to show any outward signs of ripening. This undesirable situation was also true of the test fruits. After close examination of the color records, the evidence does seem to substantiate the view that inhibition did actually occur, but this conclusion cannot under the circumstances be considered final, and the whole test bears rechecking with fruit of a more uniform nature.

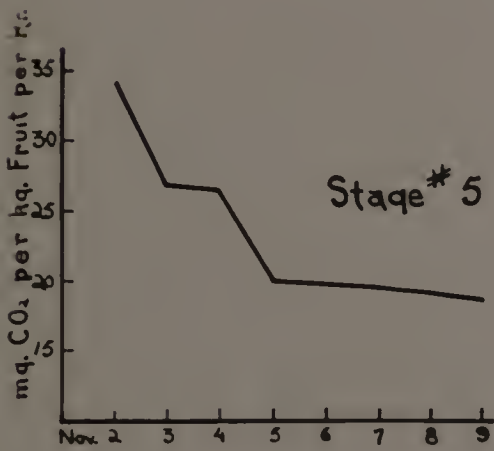
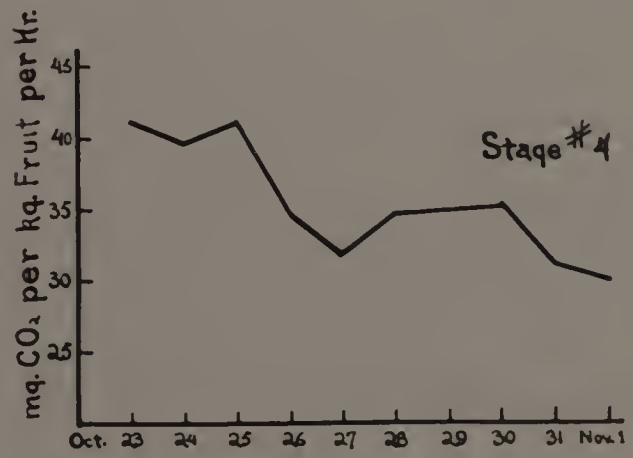
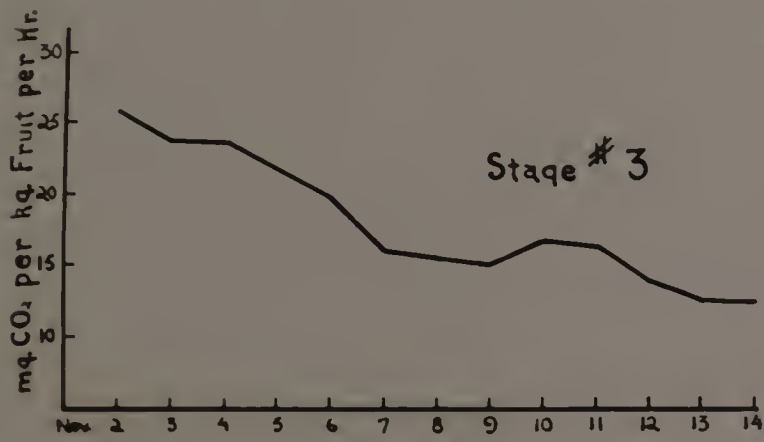
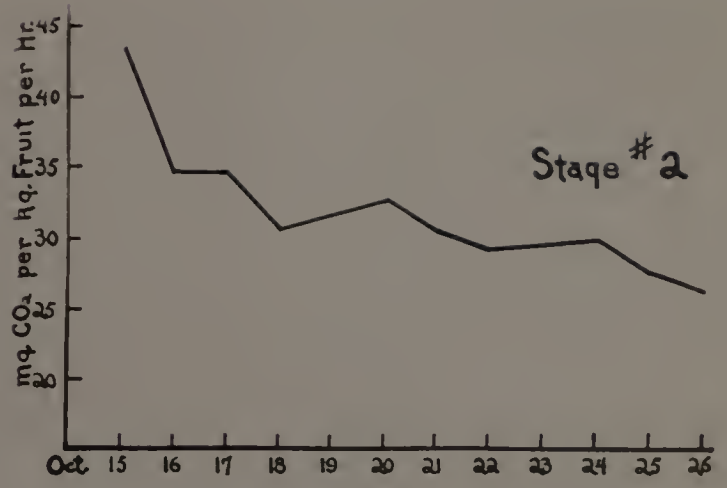
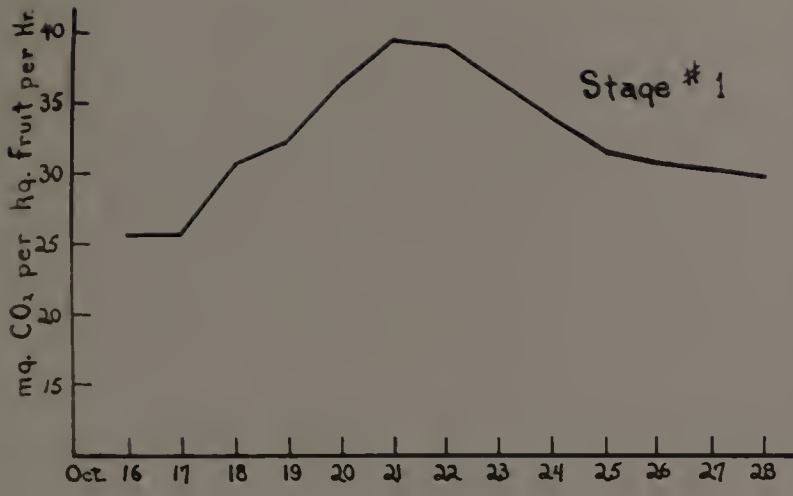


Figure 4. Respiration curves for untreated tomato fruits.

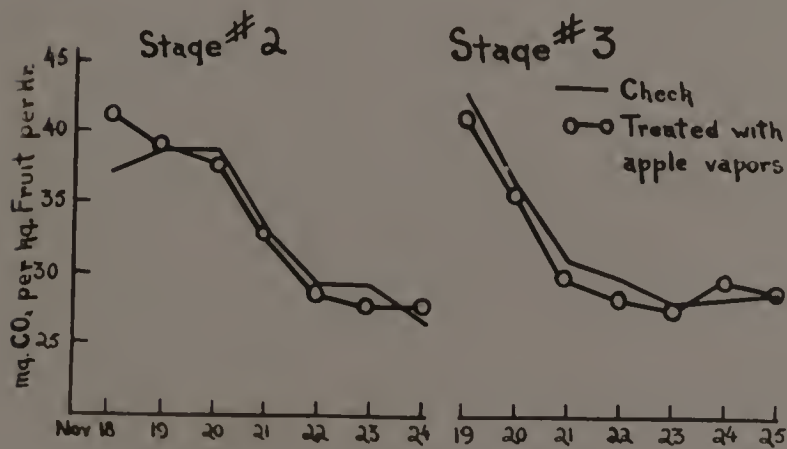
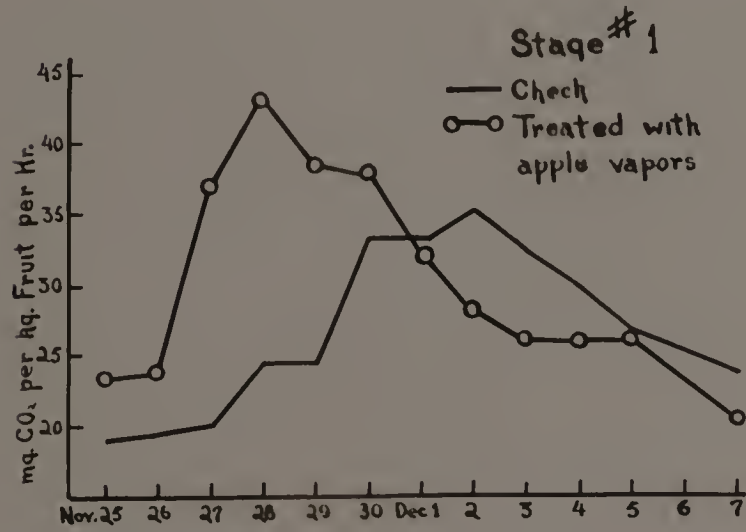
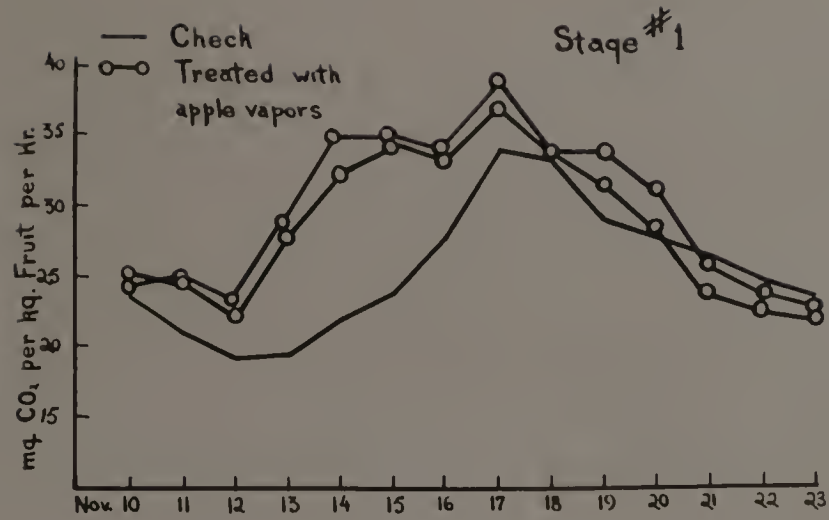


Figure 5. Respiration curves for tomato fruits treated with apple vapors.

COLOR CHANGES OF TOMATOES EXPOSED TO RIPE APPLE GASES

Expt. Started	Reading Taken	Lot	Percent of Fruit at various Stages				
			#1	#2	#3	#4	#5
Nov. 9	Nov.15	Treated	—	30.8	15.4	53.8	—
		Check	25.0	25.0	41.7	8.3	—

Fig. 6. Color record of Stage #1 tomatoes after the 6th day of treatment with ripe apple vapors.

Expt. Started	Reading Taken	Lot	Percent of Fruit at Various Stages				
			#1	#2	#3	#4	#5
Nov.17	Nov.21	Treated	—	—	14.3	57.1	28.6
		Check	—	—	7.1	57.1	35.8

Fig. 7. Color record of Stage #2 tomatoes after the 4th day of treatment with ripe apple vapors.

Expt. Started	Reading Taken	Lot	Percent of Fruit at Various Stages				
			#1	#2	#3	#4	#5
Nov.17	Nov.21	Treated	—	—	—	27.3	72.7
		Check	—	—	—	16.7	83.3

Fig. 8. Color record of Stage #3 tomatoes after the 4th day of treatment with ripe apple vapors.

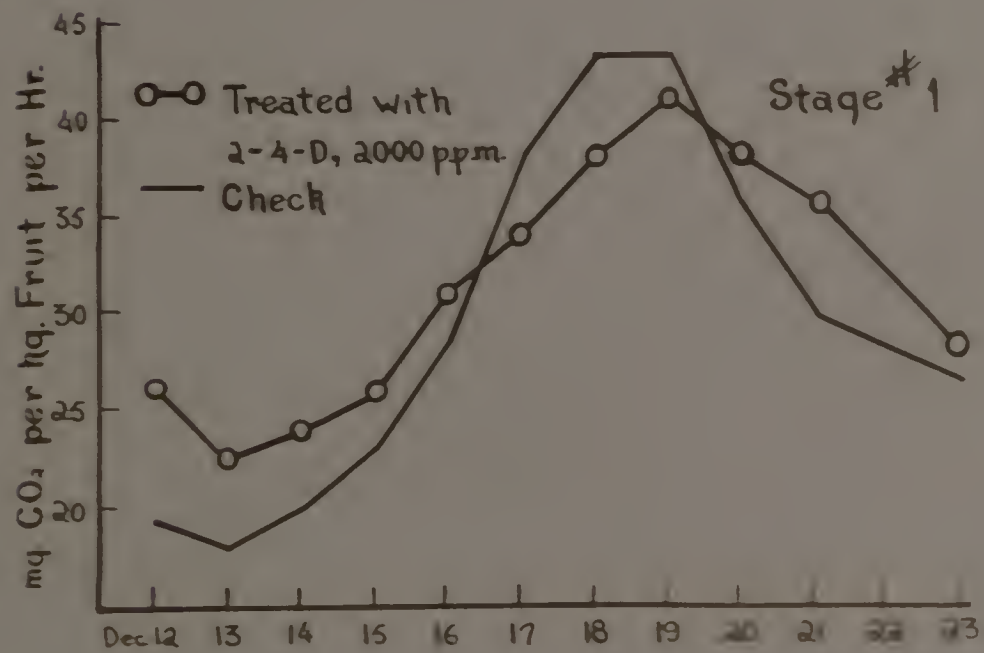
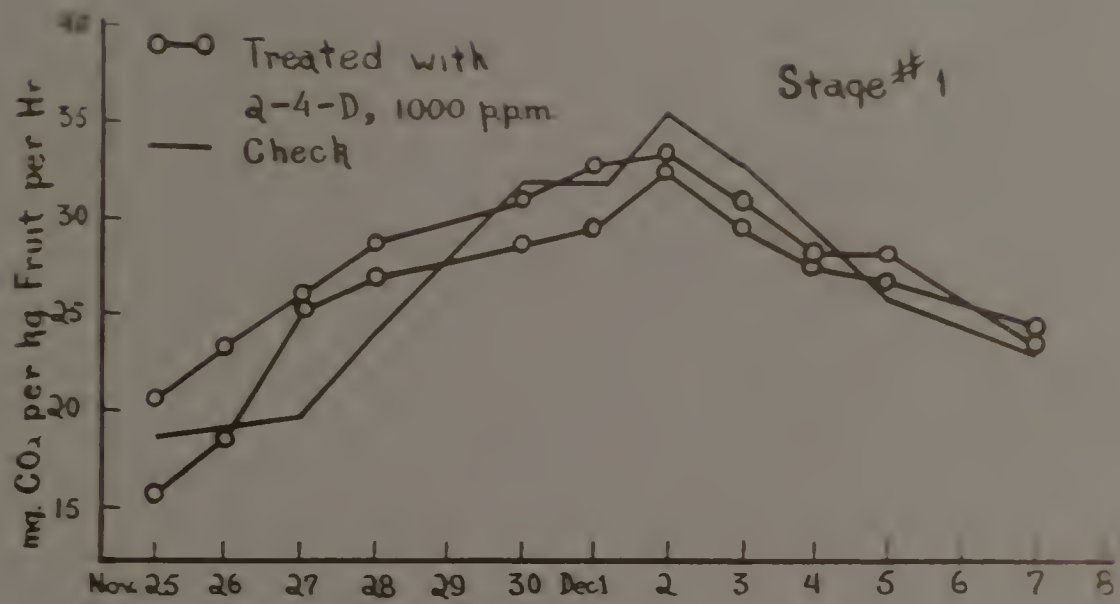


Figure 9. Respiration curves for tomatoes treated with 2,4-dichlorophenoxyacetic acid.

COLOR CHANGES OF TOMATOES TREATED WITH
2,4-DICHLOROPHENOXYACETIC ACID

Expt. Started	Reading Taken	Lot	Percent of Fruit at Various Stages				
			#1	#2	#3	#4	#5
Nov. 24	Nov. 30	Treated	—	29.1	33.3	25.0	12.6
		Checks	—	28.6	42.8	—	28.6
	Dec. 4	Treated	—	—	8.0	41.7	50.3
		Checks	—	—	13.9	28.4	57.7
Dec. 11	Dec. 15	Treated	66.6	20.0	13.4	—	—
		Check	66.6	26.0	6.6	—	—
	Dec. 18	Treated	—	33.4	53.4	13.3	—
		Check	—	—	33.3	66.7	—

Fig. 10. Color record of Stage #1 tomatoes after the 6th and 10th day, and also the 4th and 7th day of treatment with 2,4-D.

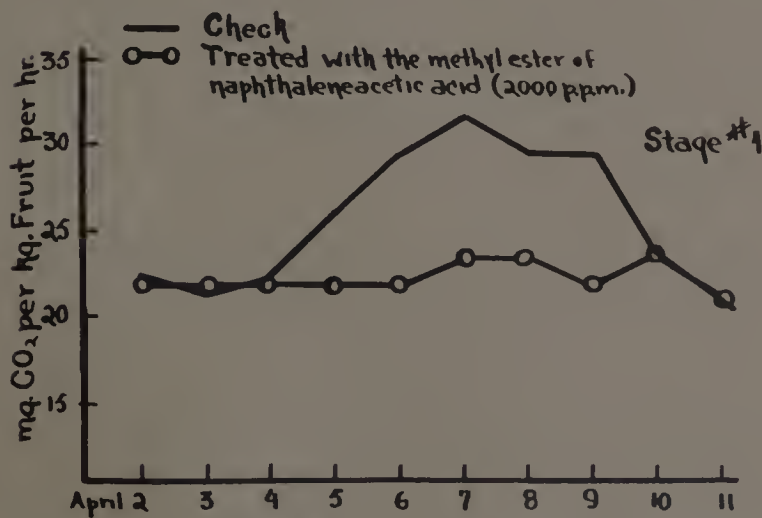
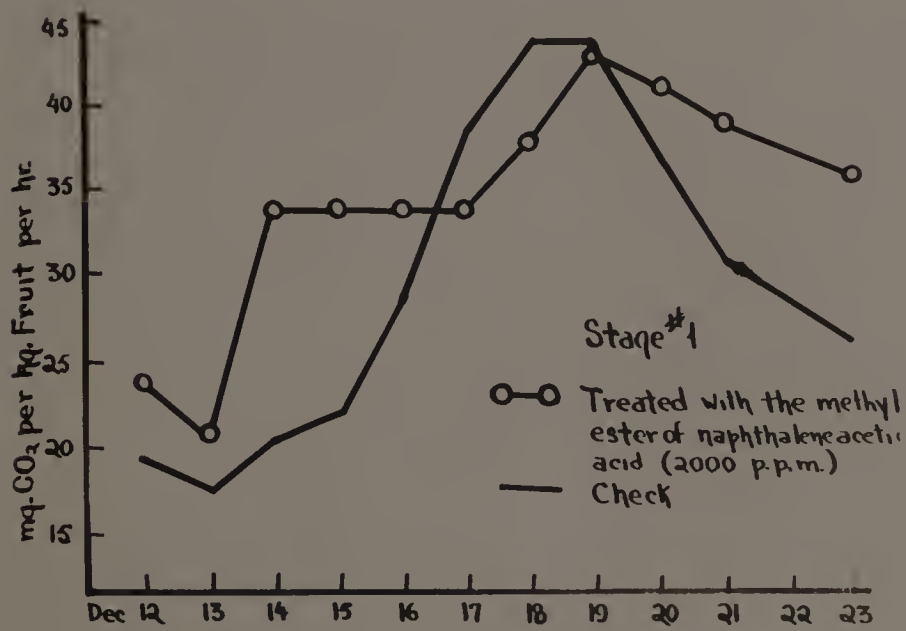
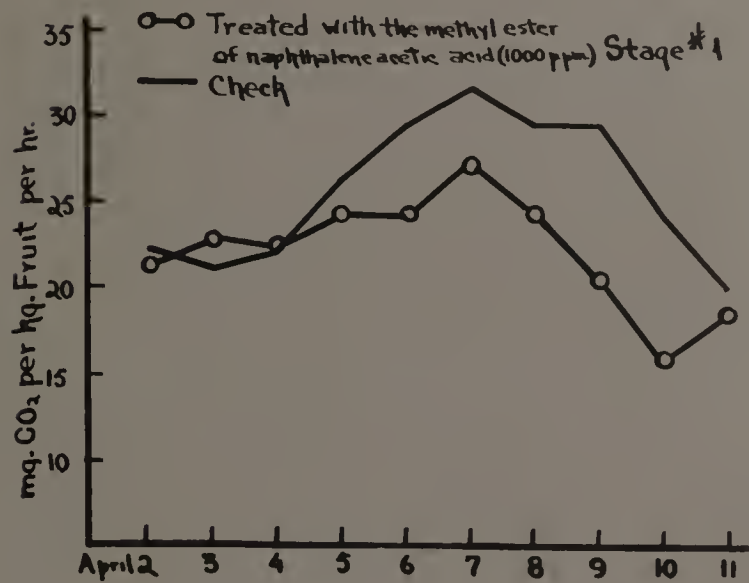
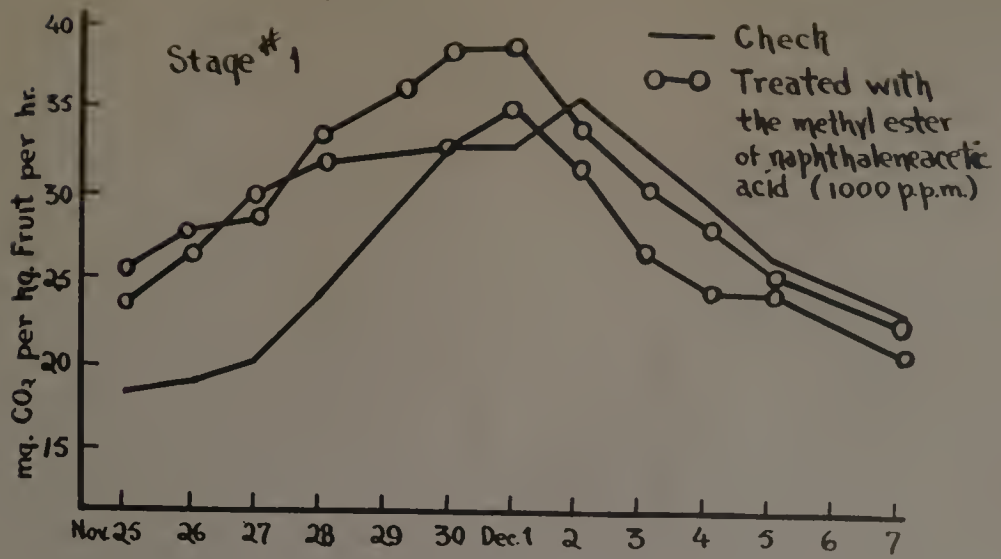


Figure 11. Respiration curves for tomatoes treated with MENAA.

COLOR CHANGES OF TOMATOES TREATED WITH THE METHYL ESTER OF NAPHTHALENEACETIC ACID

Expt. Started	Reading Taken	Lot	Percent of Fruit at Various Stages				
			#1	#2	#3	#4	#5
Nov. 14	Nov. 30	Treated	—	12.0	32.0	36.0	20.0
		Check	—	28.6	42.8	—	28.6
	Dec. 4	Treated	—	—	—	28.0	72.0
		Check	—	—	13.9	28.4	57.7
April 1	April 5	Treated	100.0	—	—	—	—
		Check	70.0	30.0	—	—	—
	April 9	Treated	—	92.0	—	—	8.0
		Check	16.0	28.0	20.0	20.0	16.0

Fig. 12. Color record of Stage #1 tomatoes after the 6th, 10th and also the 4th, 8th day of treatment with a 1000 p.p.m. solution of the methyl ester of naphthaleneacetic acid.

Dec. 11	Dec. 15	Treated	64.3	28.6	7.1	—	—
		Check	66.6	26.6	6.6	—	—
	Dec. 18	Treated	—	50.0	50.0	—	—
		Check	—	—	33.3	66.7	—
April 1	April 5	Treated	92.8	—	3.6	3.6	—
		Check	70.0	30.0	—	—	—
	April 9	Treated	—	60.7	14.4	17.8	7.1
		Check	16.0	28.0	20.0	20.0	16.0

Fig. 13. Color record of Stage #1 tomatoes after the 4th, 7th and also the 4th, 8th day of treatment with a 2000 p.p.m. solution of the methyl ester of naphthaleneacetic acid.

PART "B"

Experiment # 1. The Effect of Geon 31X³, Geon 31X plus 2,4-Dichlorophenoxyacetic Acid, and Geon 31X plus the Methyl Ester of Naphthalene-acetic Acid on Tomato Fruit Respiration..

Stage #1 fruits were harvested in December of 1948 and subjected to one of the following treatments:

- (a) Straight Geon 31X at a concentration of 1 part Geon 31X to 20 parts of water.
- (b) A mixture of Geon 31X at a 1:20 concentration and 2,4-D at a strength of 2000 p.p.m.
- (c) A mixture of Geon 31X at a 1:20 concentration and the methyl ester of naphthaleneacetic acid at a strength of 2000 p.p.m.

The test fruits were dipped into their respective solution and then placed in the respiratory apparatus for study.

Duplicate untreated fruits were used as checks. The respiration and color change data are recorded on pages 47 and 48.

The respiration curve of the fruits treated with a straight Geon 31X solution followed very closely that of the check fruits. Although no prominent influence is noted in the respiration data a slight retardation is indicated.

³Geon 31X is a water dispersed formulation of polyvinyl resin composed of 55 percent solids.

The color change data indicate more definitely that the rate of ripening had been reduced by the treatment.

Tomatoes exposed to a mixture of Geon 31X and 2,4-D showed a marked reduction in respiration rate with comparison to corresponding check fruits. The treated fruits commenced their climacteric rise at a later date than did the checks, and also reached the peak of their curve one day later than did the checks. Information of fruit color change corroborates these findings, it having been found that the treated fruits lagged behind the checks in the matter of color development during the course of the experiment.

The fruits treated with Geon 31X plus the methyl ester of naphthaleneacetic acid commenced their climacteric rise at the same time as did the checks, but remained at a lower level of respiration intensity throughout the greater portion of the experiment. The climacteric point was also reached at a later date by the treated fruits than the check fruits. The color change record contends that the metabolism of the treated fruits was at a lower level than that of the checks, thus harmonizing well with the respiratory findings.

It seems from these results that a mixture of Geon 31X with either 2,4-D or the methyl ester of naphthaleneacetic acid has an inhibiting effect upon tomato respiratory and color development processes. The exact effect of a straight Geon 31X treatment was not decisively established by these tests, and remains a matter for future work.

Experiment # 2. The Effect of Sealing Certain Surface Areas of the Tomato Fruit with Wax upon the Respiration of that Fruit.

Experiments in which specific areas of the tomato were waxed over have been a matter of interest to certain past workers mentioned in the literature review section of this paper. Although some of the tests which follow are in certain respects a duplication of some of these earlier works, they were initiated to study first hand the results of the treatments.

Stage #1 fruits were harvested in December of 1948 as well as in April of 1949⁴, their stem scar areas sealed with paraffin, after which they were studied in comparison with similar untreated fruits with respect to respiration and color development tendencies. The results of this study are published on pages 49 and 50.

An immediate reduction in the amount of carbon dioxide liberated by the test fruits occurred. This was followed by a level period of production in which the quantity of carbon dioxide emanated by the fruits varied but little from day to day. This period of stability was maintained throughout the remainder of the experiment.

⁴The fruits of this spring season were of the same highly variable degree of maturity as those of like season described in Experiment #2 of Part "A". However, the resulting effect of the wax treatments was so drastic in the tests which follow that little doubt remained at the end of each test as to the specific effect of the treatment.

The results of this test agree in principle with similar work done by Brooks (7) and Clendenning (14, 15, 16). In all cases the rate of respiration and maturation of tomatoes with sealed stem scar regions was greatly impeded. However, the results of this last test do take issue with these authors when they state that all gaseous exchange for the tomato fruit takes place in the afore mentioned surface area. In the experiment just presented it was shown that although the rate of fruit respiration and maturation was seriously restricted by the process of sealing this vital area, some gas did manage to escape from the fruit. This point tends to foster the view that other regions besides those encompassed by the stem scar area may be responsible for the passage of a certain amount of the fruit gases.

To investigate this matter further, Stage #1 fruits, which were picked in April of 1949, were subjected to either of two treatments. In one test the entire surface of the tomato was waxed over, while in the second test the same procedure was followed except that the stem scar area of the fruit was untouched and remained unsealed. The results of these tests are presented on pages 49 and 50.

The fruits with untreated stem scar areas showed little significant deviation in respiration trend and intensity from their respective checks. Ripening was also of a similar rate in both lots of fruits. Waxing over just

the skin of the tomato fruit had little effect on the fruit's metabolic activities.

A rather unexpected phenomenon occurred in the case of the tomatoes which were waxed over in entirety. After the second day of treatment little eruptions began to appear in the wax cover of the fruit. With the passage of time these eruptions grew into bubbles which resembled small blisters. These bubbles increased in size until puncture of the strained wax cover apparently occurred, after which they ceased expansion. Some bubbles obtained a size of about 1/4 inch in height. A study of the respiration curve for these fruits revealed an extremely low initial rate of carbon dioxide production. The rate increased greatly by the time of the second reading, after which it displayed a somewhat constant rate of production for a large part of the remainder of the test. Color records show a marked inhibition in the development of red color for the treated fruits. Upon termination of the experiment these fruits were placed on a shelf next to those which had only the stem scar area sealed. It was of interest to note that while the stem scar sealed fruits eventually did ripen into apparently normal mature fruits, the specimens which were coated with paraffin in entirety showed no progress in this direction but remained in a very immature condition until, after three weeks, internal breakdown of the fruits occurred. It is evident from this observation that the physiological disturbance imposed upon

tomatoes which are entirely enclosed in wax is much more pronounced than that caused by merely sealing over the stem scar area of the fruit.

Experiment # 3. The Effect of the Vapors of Ripe Tomatoes upon the Respiration of other Tomatoes.

The following tests were performed before it was realized, as a result of experimentation with apple vapors (Expt. #2 of Part "A"), that only Stage #1 tomatoes are responsive to treatment. Therefore, lots representing a complete set of maturity stages were each subjected to the gaseous products of about 1000 grams of ripe tomatoes in much the same manner employed in experiment #2 of Part "A" with ripe apple vapors. The respiration and color development studies took place in November of 1948 and the results are given on pages 51 and 52.

Treated fruits of Stage #1 manifested a lower respiration rate than their respective checks and the data suggest that the treatment possessed properties of inhibition. The color data, however, do not support this view, and show little difference in color change rate of treated and untreated fruits.

Tomatoes of Stages #2 through #5 showed no response to tomato vapors, and followed closely the downward trend in respiration rate of their respective checks. The color change

data substantiate the respiration findings, showing the treatment to have little or no effect on fruits beyond the mature-green stage of maturity.

The respiration curve representative of the treated fruits of Stage #4, although simulating closely the curve of the corresponding checks, was in a much higher position on the graph than was that of the checks. Upon investigation it was found that the rate of air flow over the check lot was much slower than that over the treated lot (less than 0.01 cubic feet per minute).. As previously stated, research showed that the relative position of a curve on a graph depended, within limits, upon the rate of air flow, the critical level being 0.01 cubic feet per minute. Any reading below this figure tended to lower the position of the resulting curve on the graph. Therefore, it can be safely assumed that the low position of the curve for the check fruits was a direct result of a low rate of air flow for this lot.

Experiment # 4. Determination of the Presence of Ethylene
in the Volatile Products of Mature-Green
and Ripe Tomato Fruits.

This experiment was conducted to determine whether ethylene was present in the vapors liberated by tomato fruits of different maturities. Detection of this gas was made by means of ethylene sensitive indicator plants. Tomato, potato, and castor bean seedlings are among those plants which have

been known for some time to produce prominent epinastic reactions when exposed to ethylene, and have been used widely in the past for the detection of this gas (17, 19, 20, 22, 24, 29, 30, 45, 46). Harvey (32) describes the plant response to ethylene as a nastic drooping of leaves. He found a concentration of ethylene as low as 1:100,000,000 to be effective in producing epinastic responses in castor bean plants. Zimmerman, Hitchcock, and Crocker (73) put the effective rate for tomato seedlings as low as 1:5,000,000.

Three sets of apparatus, as diagrammed on page 19, were constructed. In the first set the gaseous emanations of 1000 grams of ripe tomato fruits were passed over a tomato seedling which acted as the indicator plant. In the second set 1000 grams of ripe apples were substituted for the tomatoes, while in the third set only untreated air from the surrounding atmosphere was passed over a seedling. These tests were conducted in January of 1940.

After 17 hours of treatment the plant exposed to the vapors of ripe apples showed noticeable signs of epinasty, while the plant treated with the vapors of ripe tomatoes was affected but little (Fig. 27). The plant treated with the vapors of apples also showed these signs of epinasty much sooner than did the plant treated with tomato vapors. At the end of 48 hours both plants showed severe epinastic reaction, but again the plant exposed to the apple vapors

suffered the most (Fig. 28). The plant exposed only to the untreated air remained in a normal, healthy condition, and showed the outside atmosphere to be uncontaminated.

A second set of tests was carried out in April of 1949 which was in every respect identical to the one just described, with the exception that green tomatoes were used instead of the ripe tomatoes as a source of gas. The results of this second experiment indicate that an insignificant amount of ethylene, if any, is liberated by mature-green tomatoes (Fig. 29).

A repetition of all the tests included under this experiment showed the results, as stated above, to hold true.

It is evident from these tests that the same epinastic inducing substance (ethylene) which is given off by ripe apples and which is considered to be a stimulating agent, is also given off by ripe tomatoes, but apparently not to so great a degree. Very little, if any, of this substance is liberated by green tomatoes.

Experiment # 5. The Effects of Treated Tomato Vapors on the Respiration of other Tomatoes.

The last two experiments showed that although ripe tomatoes gave off a vaporous substance which produced epinastic reactions identical to those caused by the active

ingredient (ethylene) of ripe apple gases, these tomato gases had no stimulating effect on Stave #1 test tomatoes. These two points, (a) the content of ethylene in tomato emanations, and (b) the failure of these gases to show powers of stimulation, are in complete contradiction of one another. In an attempted explanation of these peculiar findings it was reasoned that perhaps the stimulating properties of the ethylene contained in the tomato vapors are masked or neutralized by the presence of an inhibitor also contained in the same gases. Thus, the next test was designed to subject the tomato gases to an ethylene absorbent before allowing them to be passed over responsive test fruits. By eliminating the ethylene from the vapors in this way, it was hoped to bring out the effect of the suspected inhibitor. At the same time other tomato vapors were passed through a material which, it was hoped, would separate out the inhibitor, thus allowing the ethylene to react without interference.

The adsorptive power of bromine for ethylene has been well established by Elmer (22), Smith and Gane (62), Smock (57), Southwick (68), Pratt, Young and Biale (53) and others. Southwick also found that activated charcoal was an inefficient adsorbent for ethylene when used as described later, but once this charcoal was subjected to bromine it became an efficient adsorbent for this gas.

Therefore, brominated activated charcoal was used in the following tests as the ethylene adsorbent. The activated charcoal was also employed in the untreated form as a possible adsorbent for the inhibitor whose presence in tomato gases was suspected.

In April of 1949 four adsorption towers consisting of glass cylinders 2 feet in length and 24 mm. in diameter were connected to separate air inlets of the respiration machine. The water bubblers of the machine, which formerly acted as humidifying devices, were moved from their old position and inserted between the newly erected adsorption towers and the carbon dioxide wash bottles. In this way the bubblers not only acted in their original capacity as humidifiers, but also served as water traps for what bromine gas or charcoal particles passed over from the towers by action of the air stream during the course of the tests.

Two of the towers were each filled with 100 grams of activated charcoal⁵ which had first been treated with 12 ml. of bromine. These towers acted as ethylene adsorbers. The other two towers were each filled with 100 grams of untreated activated charcoal, and acted as possible adsorbers of the suspected inhibitor. The gases of 1000 gram lots of

⁵The carbon mentioned throughout this paper is activated coconut shell carbon (Columbia 4-16 mesh).

ripe tomatoes were passed through the towers and then over lots of Stage #1 test fruits. Similar untreated fruits were used as checks. The respiration as well as the color readings for similarly treated lots were averaged. The final results of the experiment are presented on pages 55 and 56.

The respiration curve of the fruits treated with the ethylene free vapors showed little change from that of the checks. The development of fruit color was shown to be slightly more rapid in the case of the treated fruits than in the case of the checks, but this difference was too small to be significant.

The fruits treated with vapors which were first passed through activated charcoal showed no significant difference in respiration or speed of color development from their respective checks.

It is evident from these tests that the passage of tomato vapors through activated charcoal or brominated activated charcoal alters little the ultimate effect of these vapors on the respiration and color development processes of responsive tomato fruits. It is also evident that the results of these tests do not seem to substantiate the theory presented in the beginning paragraph of this experiment. However, it is conceivable that the activated carbon failed to adsorb the inhibitor if it was present.

Experiment # 6. The Effectiveness of Brominated, Activated Charcoal, and of Untreated Activated Charcoal as Adsorbents for Ethylene contained in Tomato Vapors.

As a follow up of work performed in Experiment #5 of Part "B", tests were initiated to determine with certainty to what extent the ethylene in tomato vapors was adsorbed by brominated, activated charcoal, and whether the epinastic quality of tomato vapors was altered by their passage through untreated activated charcoal. To this end, the gases of 1000 gram lots of ripe tomatoes were passed through the same adsorption towers as described in Experiment #5 of this section. However, the gases, upon leaving the towers, were next directed over tomato seedlings instead of test lots of tomato fruits. In addition to the seedlings treated with tomato vapors, other seedlings were exposed to the emanations of ripe apples while still others served as controls. The studies were carried out in April of 1949.

Photographs illustrating the condition of the seedlings after 48 hours of treatment are presented on page 57, and show the check seedling as well as the seedling treated with tomato vapors passed through brominated charcoal to have suffered little during the course of the experiment. However, the seedling exposed to the apple vapors as well as that exposed to the vapors of tomatoes which were first

passed through activated charcoal showed noticeable signs of epinasty after this period of time. Of the two seedlings which showed signs of epinasty, the one treated with apple vapors suffered more severely and at an earlier date than did its companion.

These tests confirm that brominated, activated charcoal serves as an excellent adsorbent for ethylene, while untreated activated charcoal lacks this quality when used as described here.

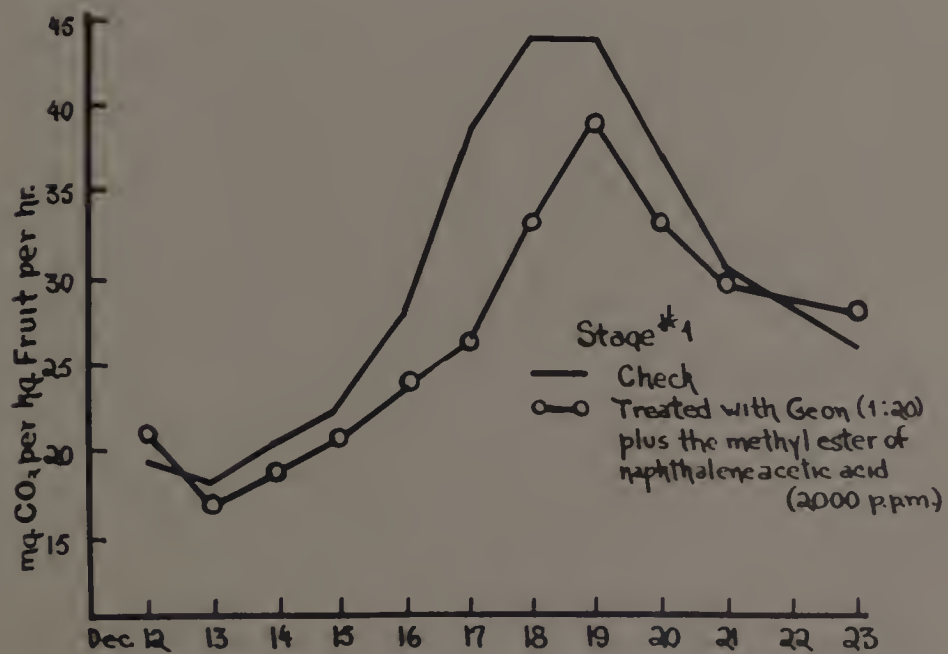
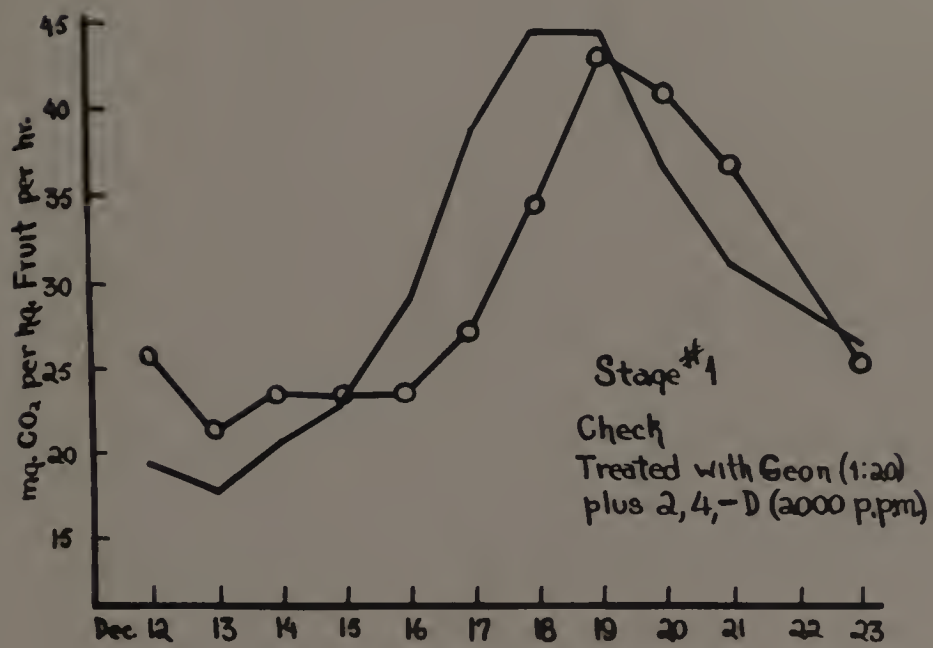
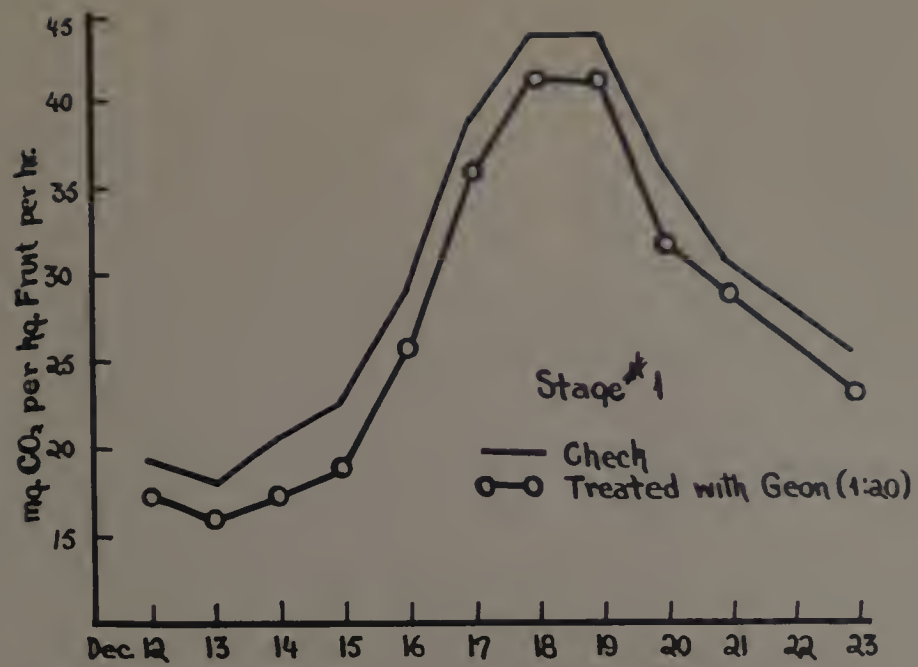


Figure 14. Respiration curves of tomatoes treated with different Geon 31X mixtures.

COLOR CHANGES OF TOMATOES EXPOSED TO DIFFERENT GEON 31X MIXTURES

Expt. Started	Reading Taken	Lot	Percent of Fruit at Various States				
			#1	#2	#3	#4	#5
Dec. 11	Dec. 15	Treated	81.3	18.7	--	--	--
		Check	66.6	26.6	--	--	--
	Dec. 18	Treated	--	31.3	43.7	25.0	--
		Check	--	--	33.3	66.7	--

Fig. 15. Color record of Stage #1 tomatoes after the 4th and 7th day of treatment with Geon 31X.

Dec. 11	Dec. 15	Treated	68.7	25.0	6.3	--	--
		Check	66.6	26.6	6.8	--	--
	Dec. 18	Treated	--	75.0	18.7	6.3	--
		Check	--	--	33.3	66.7	--

Fig. 16. Color record of Stage #1 tomatoes after the 4th and 7th day of treatment with a Geon 31X - 2,4-D mixture.

Dec. 11	Dec. 15	Treated	70.6	23.5	5.0	--	--
		Check	66.6	26.6	6.8	--	--
	Dec. 18	Treated	--	64.7	23.5	11.8	--
		Check	--	--	33.4	66.6	--

Fig. 17. Color record of Stage #1 tomatoes after the 4th and 7th day of treatment with a Geon 31X - naphthalene-acetic acid mixture.

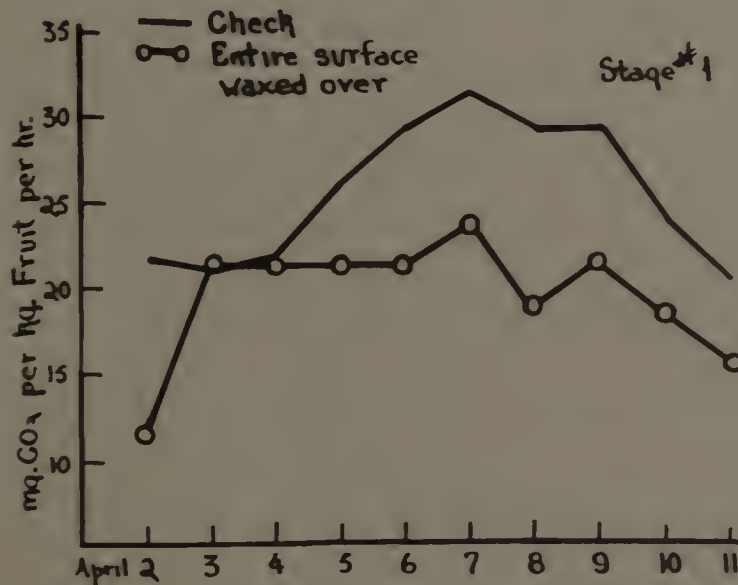
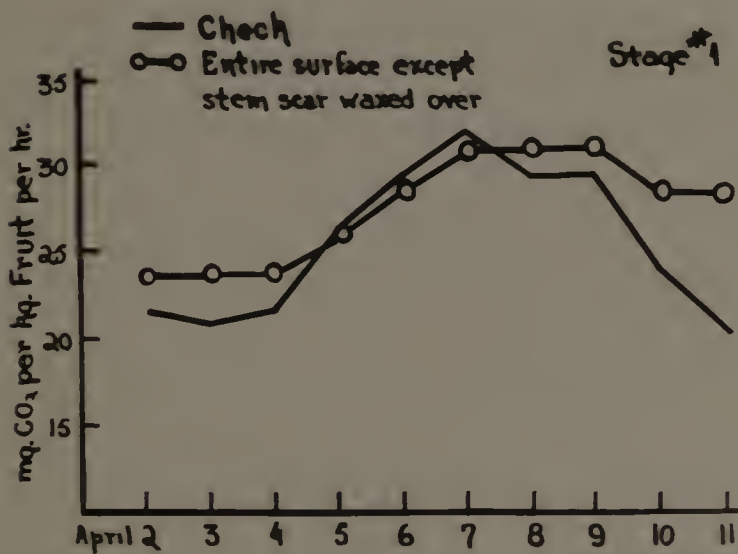
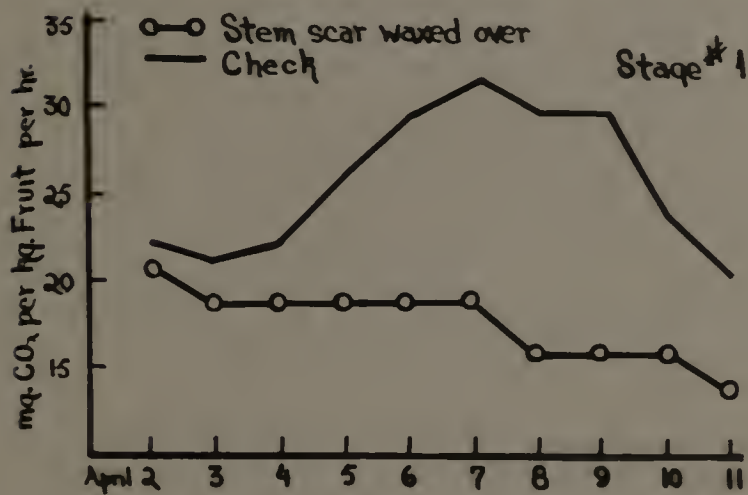
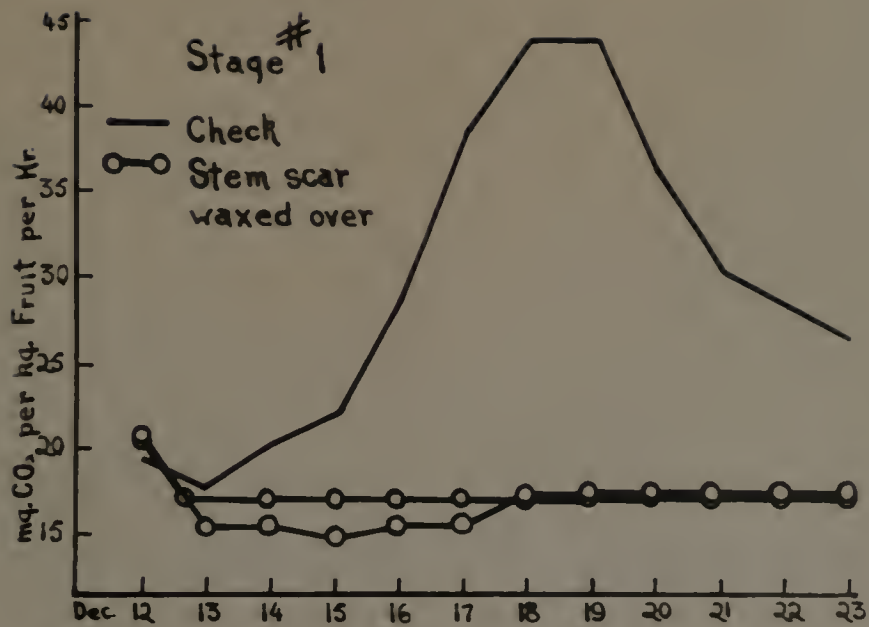


Figure 18. Respiration curves for wax treated tomatoes.

COLOR CHANGES OF TOMATOES SUBJECTED TO VARIOUS
WAX TREATMENTS

Expt. Started	Reading Taken	Lot	Percent of Fruit at Various Stages				
			#1	#2	#3	#4	#5
Dec. 11	Dec. 15	Treated	77.5	16.2	6.3	--	--
		Check	66.6	26.0	6.6	--	--
	Dec. 18	Treated	21.0	61.0	13.1	3.1	--
		Check	--	--	33.3	66.7	--
April 1	April 5	Treated	100.0	--	--	--	--
		Check	100.0	--	--	--	--
	April 9	Treated	50.0	50.0	--	--	--
		Check	16.0	28.0	20.0	20.0	16.0

Fig. 19. Color record of Stage #1 tomatoes the 4th, 7th and also the 4th, 8th day after their stem scars were waxed over.

April 1	April 5	Treated	92.8	--	--	7.2	--
		Check	100.0	--	--	--	--
	April 9	Treated	--	35.7	21.4	28.6	14.3
		Check	16.0	28.0	20.0	20.0	16.0

Fig. 20. Color record of Stage #1 tomatoes the 4th and 8th day after their skins were waxed over.

April 1	April 5	Treated	100.0	--	--	--	--
		Check	100.0	--	--	--	--
	April 9	Treated	45.2	45.2	7.6	--	--
		Check	16.0	28.0	20.0	20.0	16.0

Fig. 21. Color record of Stage #1 tomatoes the 4th and 8th day after their entire surfaces were waxed over.

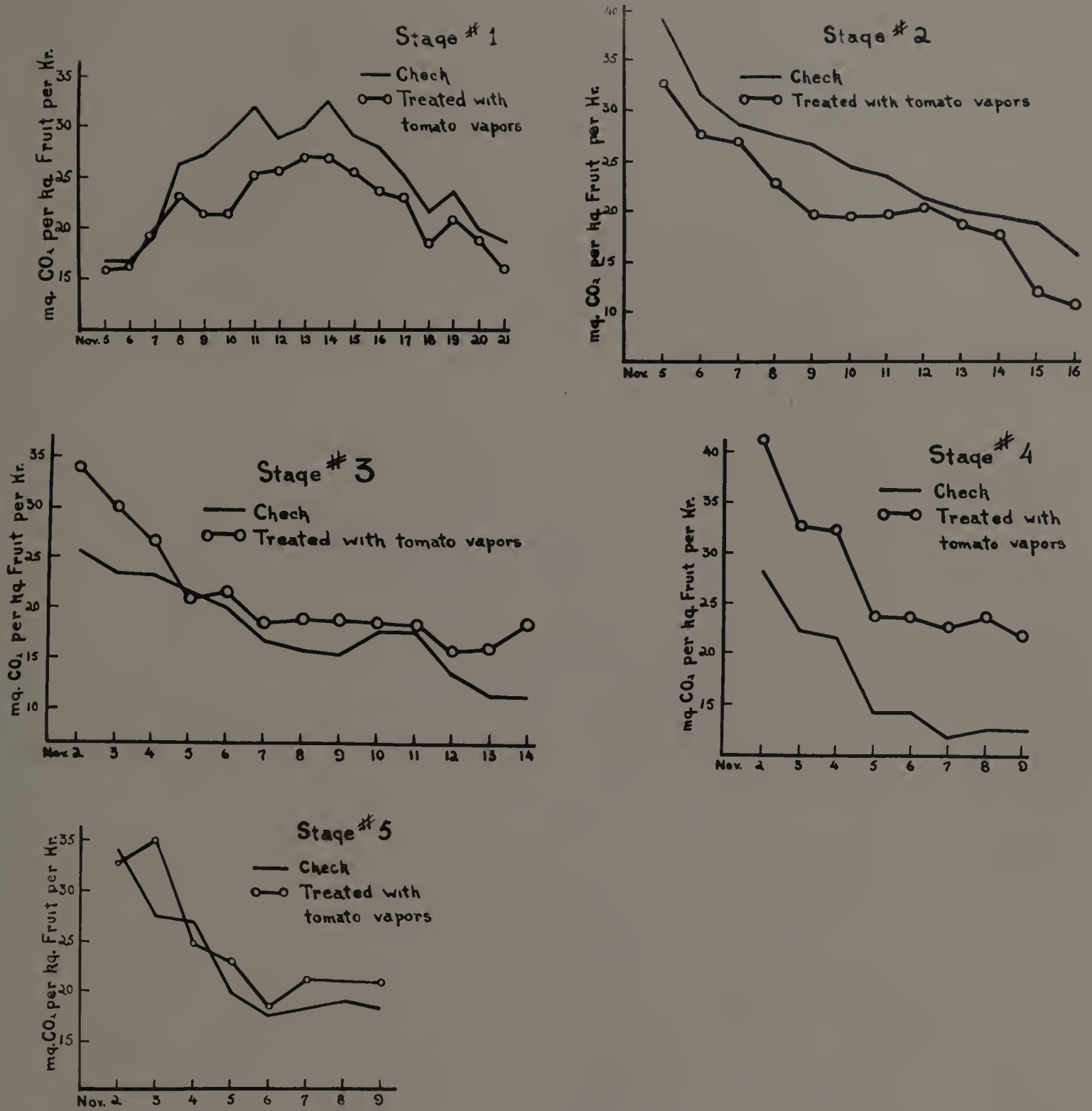


Figure 22. Respiration curves for tomatoes treated with the vapors of ripe tomatoes.

COLOR CHANGES OF TOMATOES EXPOSED TO THE VAPORS OF
RIPE TOMATOES

Expt. Started	Reading Taken	Lot	Percent of Fruit at Various Stages				
			#1	#2	#3	#4	#5
Nov. 4	Nov. 14	Treated	--	--	55.0	35.0	10.0
		Check	--	--	50.0	40.0	10.0

Fig. 23. Color record of Stage #1 tomatoes after the 10th day of treatment with the vapors of ripe tomatoes.

Nov. 4	Nov. 10	Treated	--	--	33.3	26.7	40.0
		Check	--	--	13.3	53.3	33.4

Fig. 24. Color record of Stage #2 tomatoes after the 6th day of treatment with the vapors of ripe tomatoes.

Nov. 1	Nov. 6.	Treated	--	--	17.6	59.1	27.3
		Check	--	--	--	61.1	38.0

Fig. 25. Color record of Stage #3 tomatoes after the 5th day of treatment with the vapors of ripe tomatoes.

Nov. 1	Nov. 6	Treated	--	--	--	--	100.0
		Check	--	--	--	--	100.0

Fig. 26. Color record of Stage #4 tomatoes after the 5th day of treatment with the vapors of ripe tomatoes.

Nov. 1	Nov. 6	Treated	--	--	--	--	100.0
		Check	--	--	--	--	100.0

Fig. 26. Color record of Stage #5 tomatoes after the 5th day of treatment with vapors of ripe tomatoes.



Figure 27 & 28. Tomato seedlings after exposure of 17 and 48 hours respectively to (1) untreated air (2) vapors of ripe tomatoes (3) vapors of ripe apples.



Figure 29. Tomato seedlings after exposure of 48 hours to (1) untreated air (2) vapors of green tomatoes (3) vapors of ripe apples.

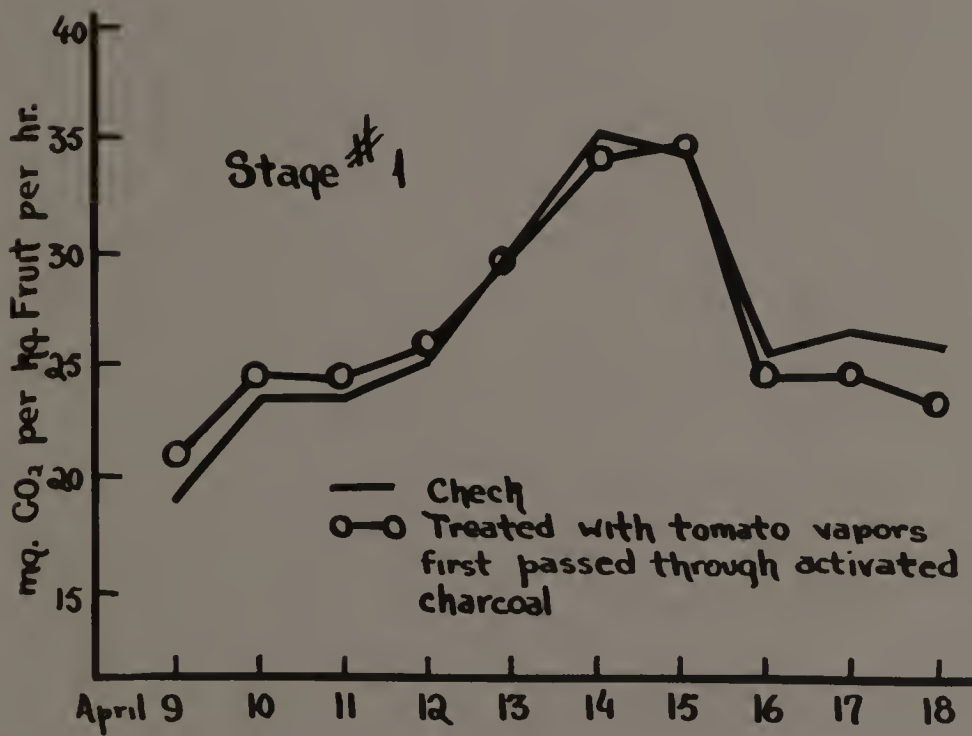
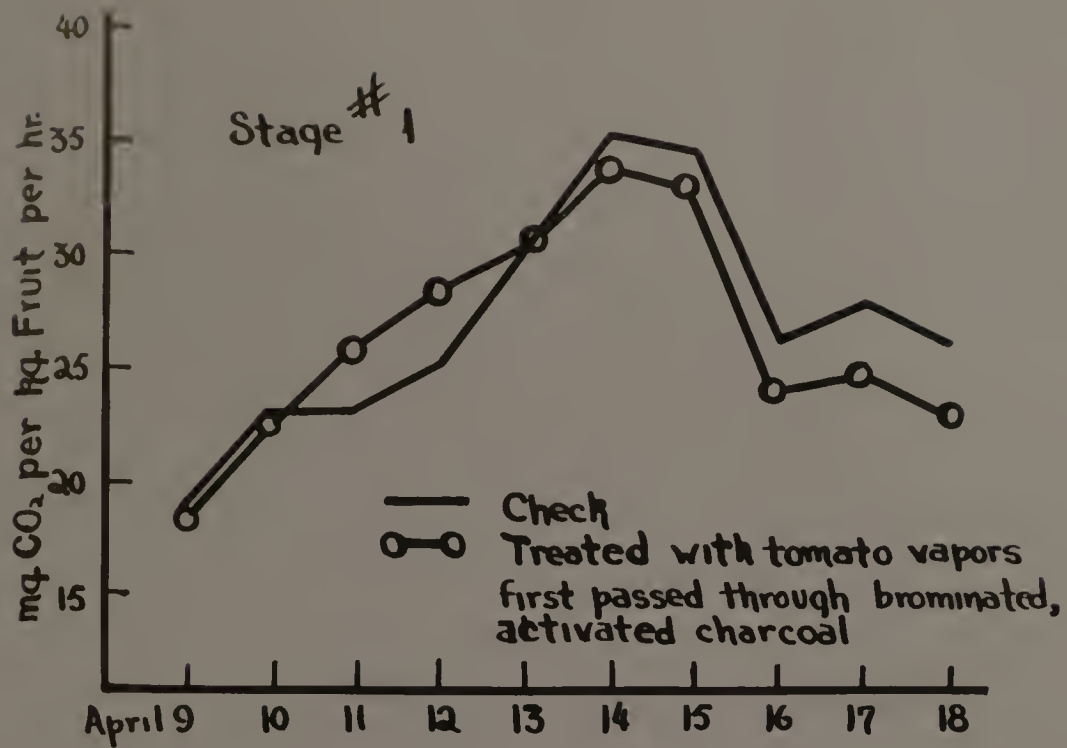


Figure 30. Respiration curves for tomatoes exposed to treated tomato vapors.

COLOR CHANGES OF TOMATOES SUBJECTED TO TREATED

VAPORS OF RIPE TOMATOES

Expt. Started	Reading Taken	Lot	Percent of Fruit at Various Stages				
			#1	#2	#3	#4	#5
April 6	April 12	Treated	55.5	26.0	18.5	—	—
		Check	70.4	11.1	18.5	—	—
	April 15	Treated	—	37.1	22.2	22.2	18.5
		Check	—	47.8	14.8	30.0	7.4

Fig. 31. Color record of Stage #1 tomatoes after the 6th and 9th day of treatment with the vapors of ripe tomatoes which had first been passed through brominated, activated charcoal.

April 6	April 12	Treated	53.8	27.0	19.2	—	—
		Check	70.4	11.1	18.5	—	—
	April 15	Treated	—	50.0	19.2	15.4	15.4
		Check	—	47.8	14.8	30.0	7.4

Fig. 32. Color record of Stage #1 tomatoes after the 6th and 9th day of treatment with the vapors of ripe tomatoes which had first been passed through untreated activated charcoal.



Figure 33. Tomato seedlings after exposure of 48 hours to (1) untreated air (2) vapors of ripe tomatoes first passed through brominated, activated charcoal (3) vapors of ripe tomatoes first passed through untreated activated charcoal (4) vapors of ripe apples.

DISCUSSION

The results of this work show the tomato fruit to resemble the apple fruit in many ways with respect to respiration. These similarities can be listed as follows:

1. The climacteric rise and fall of respiration rate which is a feature of apples (5, 31, 41, 42, 51, 52, 58) has also been found to be a feature of tomatoes.
2. The tomato was found to be unresponsive to treatment once its climacteric point had been reached; the same is true of apples (39, 58, 67).
3. The stimulatory properties of apple vapors as noted by their effect on the respiration of other apples (39, 58, 61) were also manifested in the case of tomatoes.
4. The application of a thin coating of wax over the fruit is known to retard respiration in the apples (43, 58, 59). This observation was substantiated with tomatoes.
5. Apples have been known for some time to give off ethylene in their volatile emanations (22, 24, 28, 39, 48, 50). The same was found to be the case in tomatoes.

Tomato fruit respiration, however, proved to differ in some respects from apples:

1. The chemical 2,4-D, while acting as a stimulant in the case of preclimacteric apples (44, 56), had little effect on the respiration of responsive tomato

fruits.

2. The methyl ester of naphthaleneacetic acid, while displaying definite signs of being a stimulant in the case of preclimacteric apples (56, 67), reacted inconclusively in the case of preclimacteric tomatoes.
3. The volatile emanations of tomatoes were found to differ from those of apples in that they failed to stimulate the rate of respiration and red color development of preclimacteric tomatoes.

A review of the above similarities and differences is essential in the evaluation of the tomato fruit as a substitute for the apple in scale respiratory research. Fundamentally, the tomato respiration trends and tendencies do follow closely those of apples. It appears, with reference to the data which have been gathered that tomatoes may offer some promise as a substitute for apples in respiration work. However, their response to a given chemical may not always simulate those obtained from apples.

The inherent difficulty experienced with tomatoes in this work was in distinguishing fruits of identical maturities. Maturity only nature-green fruits were found to be responsive to treatment, the appearance of red color in the fruit surface could not be used as a guide to maturity. Fruit size and the nature and quality of the green surface color were all of some help, but were poor guides

posts at best. This failure to recognize maturities of green fruits resulted in the employment of fruits which appeared to be of identical maturity at the beginning of the test, but which showed noted signs of variation after a week or more of experimentation. It was found that the small very early season fruits were the most difficult to work with in this respect, and it is recommended that these fruits be discarded in future respiration studies. The study of tomato fruit respiration would be facilitated immeasurably if some device were found to accurately ascertain the stage of maturity of green tomato fruits.

An interesting point brought out by this work is that though the tomato skin is devoid of stomata (33), waxing the stem scar end of the fruit seems to impel the passage of a certain amount of gases through the fruit skin. If this transfer of gases through the fruit skin is impeded, as in the case where the entire fruit surface is coated with wax, marked physiological disturbance of the fruit occurs. This disturbance exceeds by far that imposed by waxing over just the fruit scar.

Perhaps the most controversial issue resulting from the past experiments concerns the peculiar properties displayed by the vapors of ripe tomatoes. The exact reason why these vapors containing ethylene showed no stimulatory properties is not known. There is slight indication that perhaps

too few fruits were used as a source of gas, resulting in a concentration of ethylene which was too low to be effective. This argument is substantiated in part by other experiments which showed the concentration of ethylene generated by tomatoes to be on a much lower plane than that produced by apples. It would be of interest to note, in future experiments, whether the vapors of 1000 grams of tomatoes would stimulate the respiration cycle of responsive apples and also whether an increase in the number of tomatoes used as a source of gas would result in stimulation of responsive tomatoes.

SUMMARY

A series of respiration experiments with tomato fruits was conducted, and the following conclusions established from the results:

1. Untreated mature-green tomatoes displayed a climacteric rise and fall in respiration rate during the latter portions of their ontogeny.
2. Tomatoes beyond the mature-green (preclimacteric) stage of maturity displayed a steady downward trend in respiration rate.
3. Only mature-green tomatoes were found to react to the

- stimulating properties of apple vapors.
4. The chemical 2,4-D had little effect on the respiration cycle of preclimacteric tomatoes.
 5. The methyl ester of naphthaleneacetic acid was found to react in an inconclusive manner on respiration of preclimacteric tomatoes.
 6. Geon 31X appeared to possess very slight stimulatory properties with regard to preclimacteric tomatoes.
 7. A mixture of Geon 31X plus 2,4-D as well as a mixture of Geon 31X plus the methyl ester of naphthaleneacetic acid had an inhibiting effect on tomato fruit respiration.
 8. Tomato fruits of all maturities were found to be unresponsive to the volatile products of other ripe tomatoes.
 9. Ripe tomato fruits were found to generate ethylene as a volatile product, but to a lesser degree than apples.
 10. Green tomatoes failed to give off ethylene as a volatile product.
 11. Brominated activated charcoal was found to be an efficient adsorbent for the gaseous ethylene found in the vapors of ripe tomatoes. Untreated activated charcoal was found to have little affinity for this gas when used in these experiments.
 12. Ripe tomato vapors passed through brominated activated

charcoal and also those passed through untreated activated charcoal had no effect on the respiration of preclimacteric tomatoes.

13. Waxing over the stem scar of the tomato fruit reduced materially the carbon dioxide output of the fruit.
14. Waxing the fruit skin but not the stem scar had little effect on the respiration of the fruit.
15. Waxing the entire surface of the fruit drastically reduced the carbon dioxide output of the fruit until apparent puncture of the seal occurred after which the quantity of carbon dioxide liberated by the fruit increased. The practice of sealing the fruit in entirety showed a transfer of gases to occur through the fruit skin of those fruits possessing a sealed stem scar region. The physiological disturbance of the fruit's metabolic activities caused by this entire coverage was found to be most extreme.

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