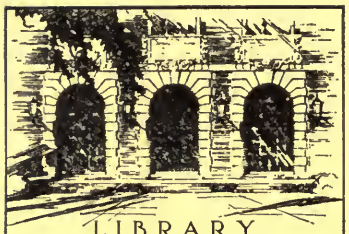

Effect of Preharvest Sprays of 2,4,5-Trichlorophenoxy-propionic Acid Upon the Maturation of Jonathan, Starking, and Golden Delicious Apples

By RICHARD V. LOTT
and ROBERT R. RICE

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CONTENTS

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Effect of Preharvest Sprays of 2,4,5-Trichlorophenoxypropionic Acid Upon the Maturation of Jonathan, Starking, and Golden Delicious Apples

RICHARD V. LOTT and ROBERT R. RICE[a]

A PRELIMINARY INVESTIGATION CONDUCTED IN 1950 to determine the effect of preharvest sprays of 2,4,5-trichlorophenoxypropionic acid[b] upon Jonathan and Golden Delicious apples bore results of potential economic significance. Golden Delicious apples showed a tendency toward cracking, softer texture, deficient aroma, less acidity, lower quality, and more pronounced post-harvest shriveling than check fruits.[16*] Moreover 2,4,5-TP, used during the summer of 1951 on important summer-maturing varieties growing in the orchards of some Illinois fruit growers and of the Agricultural Experiment Station at Urbana, caused serious crop losses on account of cracking or other manifestations of abnormal maturation. For these reasons an investigation that would determine in as much detail as possible the effects of 2,4,5-TP on the maturation of important fall-maturing varieties seemed highly desirable and was undertaken in 1951.

The three varieties chosen were Jonathan, Starking, and Golden Delicious because they are the most important of the fall-maturing varieties in Illinois, comprising about 70 percent of the tree population of the fall-maturing varieties in the state.[5]

TERMINOLOGY

In spite of the obvious need for a standard terminology in technical publications dealing with fruit quality, terms are often inconsistently and ambiguously used. This is especially true of the terminology used to describe maturation and ripening, even though these processes are major considerations in any scientific discussion of fruit quality. To

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[a] RICHARD V. LOTT, Professor of Pomology, and ROBERT R. RICE, formerly graduate assistant in Horticulture.

[b] Hereafter referred to as 2,4,5-TP. The material used in 1950 was known as formulation A-1004 and was released in 1951 as Color-Set 1004.[2]

* Superior figures refer to literature cited on page 28.

overcome this confusion, the Pomology division at the University of Illinois has adopted a specific terminology in regard to fruit quality. The terminology pertinent to this bulletin is defined below.

Morphology

The morphological terminology of Tukey and Young[27] for apples is usually followed. The pomological terms *skin* and *flesh* are added and defined as follows:

Skin — the externally visible part of the fruit; distinct from *peel,* which refers to the tissues removed in peeling.

Flesh — all the fruit tissues surrounded by epidermis except the cartilaginous pericarp and ovules (seeds).

Maturation and Ripening

The terminology of maturation and ripening described in detail by Lott[13] is used. This terminology is based on the distinction between the preharvest and post-harvest environment of the fruit.

Maturation, mature, maturity — these terms and their modifications refer to the fruit *only* while it is still attached to the tree.

M1, M2, M3, M4 — designate progressive degrees of maturation, beginning with the least degree of maturation commonly harvested commercially (M1) and continuing to the *mature* fruit (M4). For example, the first commercial picking of Transparent apples in southern Illinois is made up almost entirely of M1 fruits. The meaning of M4 or mature fruit has been defined.[13] The fraction *0.5,* added to a maturation symbol, as in M2.5, designates an intermediate stage between two degrees of maturation. An *M* number greater than *4* designates the degree of post-maturity.

Ripening, ripe, ripeness — these terms and their modifications refer to the fruit *only* after it is harvested.

Quality and Related Terms

Quality is the degree of edible desirability. It is not used to refer to condition, even though the terms *quality* and *condition* are often used synonymously in horticultural literature, particularly in trade publications.

Acceptable quality — a degree of quality that, though not definitely undesirable, fails to stimulate a desire for repeated consumption.

Satisfactory quality — a degree of quality that stimulates a desire for repeated consumption.

Poor, fair, good, very good, excellent — used to rate the quality of a given sample of apples in comparison with the highest quality attained by apples. For example, the rating *excellent* can be given only to certain samples of a few varieties. Jonathans, for instance, that are well-grown and mature are rated *excellent*. Transparent apples, on the other hand, are rated only *good* at maturity; at the immature stage at which they are commonly harvested commercially, they are rated only *fair* or slightly higher. These terms when used in conjunction with the actual composition of the fruit become much more specific, and are used whenever they add to an understanding of the materials. *Very good* and *excellent* are the approximate equivalents of *satisfactory quality*. *Good* is the approximate equivalent of *acceptable quality*. *Very poor, poor,* and *fair* are the approximate equivalents of *unacceptable quality*.

Flavor — the psychological reaction to the combination of *smell* and *taste* in a food. In dealing with fruits, the term *aroma* is commonly used instead of smell because the aromatic compounds contribute most of the smell to normal fruits. However, undesirable smells may develop from rots, foreign odors, or the products of metabolism. The term *apple aroma* is used to designate the aroma common to the mature or ripe fruits of all varieties. At the same time, each variety has a characteristic aroma which is usually much more pronounced than the apple aroma. Of the four fundamental *tastes* — sweet, sour, bitter, and salt — only the sweet taste of sugars and the sour taste of acids are common in apples, though a bitter taste sometimes occurs. Consequently flavor in apples is nearly always a combination of aromatic compounds, sugars, and acids. For detailed explanations of flavor see Crocker[6] and Moncrieff.[20]

Texture — the physical reaction or "feel" as fruits are chewed. In apples, such terms as hard, firm, crisp, mealy, juicy, and dry are used to describe texture.

Keepability — replaces the common term *keeping quality* to allow *quality* to retain a specific meaning, and signifies the degree to which

any lot of fruit retains the potential quality that it had at harvest when placed in a specific storage environment, or, conversely, the rate at which it loses its potential harvest quality in a given environment.

Condition

Condition — is a phenomenon separate and distinct from quality, concerned with freedom from and incidence of such defects as those resulting from insects, diseases, russeting, handling, and storage disorders.

Color

Background or background color — refers to the green and yellow colors and their combinations found in the skin or peel of apples. These terms replace the commonly used term *ground color* which is neither specific nor expressive of the situations encountered.

Overlying color — refers to the red colors and their modifications in conjunction with a background color.

Amount — the proportion of apple surface covered with the red color characteristic of the mature fruits of a given variety.

Intensity — the amount of red or yellow pigment per unit area of surface. *Redder* and *reddest* refer to increasing intensity of red pigment; *yellower* and *yellowest* refer to the increasing predominance of yellow over green in background color.

Flesh color — refers to color of edible tissues within the peel. It is measured near the radial center of the cortex unless otherwise stated.

Handling and Storage

Handling — any movement of the fruit from harvesting to consumption; includes picking, packing, transporting, storing, distributing, retailing, and handling by the consumer.

Storage — the environment during the *ripening* life of the apple. As soon as the fruit is separated from the tree, it is in some sort of storage environment, ranging from that environment in which the fruit is merely lying on the ground under the tree to that in special structures in which there is control of one or more of the environmental factors.

Composition

For a complete understanding of the physiological changes occurring in apples during development and senescence, the concentration of the constituents of the fruit must be expressed in amount per apple as well as in percent.

Percent or percentage — the grams of a constituent per 100 grams of material, either fresh or dry. The fresh-weight percentage is used most frequently.

Amount — the grams of a constituent in an individual apple.

Content — refers to either percent or amount in those cases in which either term is expressive of the physiological situation.

Concentration — has the same meaning as *content,* but is used most often to refer to percent.

REVIEW OF LITERATURE

Only publications that contain information about the effects of naphthaleneacetic acid[a] and 2,4,5-TP upon fall-maturing varieties during their maturation period are considered here, because NAA and 2,4,5-TP are the only preharvest sprays that have been widely used and investigated and because growers who want a drop-inhibiting spray will usually choose one of them.

Effects of NAA

Haller[9] experimented with Jonathan, Delicious, Starking, Stayman Winesap, Rome Beauty, and York Imperial apples that had received varying applications of NAA. From his pressure-test determinations he concluded that the "pre-harvest spray did not affect the firmness at harvest." Batjer and Moon[3] found that NAA did not affect the ripening of fall-maturing varieties, and from this it may be inferred that the maturation in the varieties used by these investigators was likewise unaffected.

Gerhardt and Allmendinger[8] reported that at Wenatchee, Washington, when Winesap apples were harvested at a "good stage of maturity" within 15 days from the time they were sprayed with NAA, the "maturity of the remaining fruit on the tree was not affected." They

[a] Hereafter referred to as NAA.

also stated that the maturation of Delicious apples had not been affected at the time of the first picking 15 days after the spray application, but that, by the time of the second picking (16 days after the first picking), the sprayed Delicious apples were at a more advanced stage than that of the check fruits.

Smock and Gross[22] sprayed two limbs of a McIntosh tree with the sodium salt of NAA, one at 10 p.p.m. (parts per million), the other at 20 p.p.m. concentration. The fruit picked 5 days later from each limb was 0.9 pound softer than the control fruit, which indicated that the rate of change in texture — one characteristic of maturation — was accelerated by NAA. Had these investigators given comparative data on treated and control fruit in regard to the other characteristics of maturation — background color, flesh color, and flavor — one would have obtained a better understanding of the response that McIntosh made to this treatment.

Batjer and Thompson,[4] to simulate the airplane application of drop-inhibiting sprays, applied to each of the leaves of 90 selected spurs of an Early McIntosh tree 15 droplets of NAA at 2,400 p.p.m. in a 40-percent oil emulsion with a micro-pipette. When the fruits were harvested from these spurs and from 90 check spurs 14 days later, 69 percent of the fruits from the treated spurs had 95 percent of their surface covered with red color, whereas only 2 percent of the check fruits were so colored. The effects, if any, on background color, flesh color, and flavor were not mentioned. It is apparent that the rate of red color development was stimulated by the NAA.

Southwick *et al.*[23] stated that 20 p.p.m. of NaNAA — which is double the usual concentration — hastened the softening of McIntosh apples.

Kessler,[12] discussing his investigations with McIntosh and Northern Spy in Michigan in 1949, 1950, and 1951, concluded that "preharvest sprays of NAA had no apparent effects on the chemical composition, ground color, and firmness of the harvested apples." He used concentrations of 10 and 20 p.p.m. in 1949 and 1950 and 20 p.p.m. in 1951. The degree of maturation at harvest was not stated.

In 1947 Lott[14] applied NAA at 10 p.p.m. to a group of Jonathan trees on September 19, October 1, and October 11. From these and comparable check trees, immature samples were picked on September 19, mature samples on October 4, and post-mature samples on October 17 and November 12. On the basis of changes in skin and flesh colors, sugar content, acid content, flavor, and texture, NAA did not affect the rate of maturation or the degree of quality.

In Illinois, apple growers have never reported that NAA had any specific effect on the maturation of fall-maturing varieties, despite the fact that they use two, three, and sometimes four applications of NAA. Neither has any effect on maturation been encountered by the senior author during several seasons of extensive observations throughout the apple-growing regions of the state. These statements do not include McIntosh and Early McIntosh because they are grown only to a very limited extent in Illinois.

Effects of 2,4,5-TP

As the result of a test of 2,4,5-TP on Jonathan and Golden Delicious in 1950, Lott[16] warned Illinois growers that abnormal maturation, manifested by softer texture and lower quality, could be expected in Golden Delicious in some cases at least, and probably also in summer-maturing varieties.

Thompson,[25] using NAA-treated fruits as checks usually, compared the effects of different concentrations and times of application of 2,4,5-TP on several fall-maturing varieties. His conclusions can be summarized as follows:

1. McIntosh (NAA check): No difference between treatments either in color or in other characteristics of maturation. From his statement, "This block was picked earlier than would have been desirable from the experimental standpoint," it appears that the fruit was immature at harvest. Some effect from 2,4,5-TP might have occurred if the fruit had been allowed to become mature.

2. Delicious (NAA check): On the basis of "yellow ground color, a waxy finish on the surface of the apples, and the development of water core," fruit that had been sprayed with 2,4,5-TP at a concentration of 20 p.p.m. matured earlier than the check fruits or fruits sprayed with other concentrations of 2,4,5-TP.

3. York Imperial (unsprayed check): "Pressure tests on samples taken at harvest showed no difference in maturity between lots of fruit from the various treatments." The degree of maturation at harvest was not stated.

4. Red Rome (NAA check): "Pressure tests shortly after harvest indicated that no treatment resulted in significantly more mature fruit than that from the check trees." The degree of maturation at harvest was not given.

5. Gallia Beauty (NAA check): "At harvest all of the fruit produced on the periphery of the trees was somewhat past prime picking

condition. No differences in color or maturity were observed between check fruits and those which were sprayed with 2,4,5-TP." The extent to which the samples were made up of this exterior fruit was not stated.

Hoffman and Edgerton[10] reported that early applications of 2,4,5-TP resulted in "measurably riper" McIntosh fruit at harvest time than late applications. Neither the date of picking nor the time of maturity was given; the measure of the degree of maturation was apparently firmness.

Davidson[7] published the results of tests conducted in 1950 and 1951 in which 2,4,5-TP was used on four major varieties growing in five orchards in southwestern Michigan. Using pressure tests as the measure of firmness, he concluded:

1. McIntosh (unsprayed check): One or two applications of 2,4,5-TP at a concentration of 20 p.p.m. did not decrease firmness at harvest, but three applications did. He noted, however, that the fruit that had received the three applications should have been picked 2 or 3 days earlier to have been of "proper maturity for picking."

2. Golden Delicious (unsprayed check): In comparison with the check and with a single application of 2,4,5-TP at 20 p.p.m. made 7 days before harvest (between which no difference was found), a single application of 2,4,5-TP at 20 p.p.m. made three weeks prior to harvest hastened maturity by 3 or 4 days. "Color and texture of these fruits [from the application made 3 weeks before harvest] when examined earlier indicated that they should have been picked 3 or 4 days prior to the time the other fruit in this block was harvested." He apparently felt that there would have been no difference in firmness if the fruit from these treatments had been harvested at the same stage of maturation.

3. Starking (unsprayed check): An application of 2,4,5-TP at a concentration of 20 p.p.m. 6 weeks before harvest did not affect the firmness of the apples at harvest time, compared with the check and with fruit that had received a 20-p.p.m. application 2 weeks before harvest.

4. Baldwin (unsprayed check): Apples that had received two 20-p.p.m. applications of 2,4,5-TP at 8 weeks and at 5 days before harvest were softer than the check or those that had received a single application of 2,4,5-TP at 20 p.p.m. 4 weeks before harvest.

Thompson,[26] who experimented in 1951 with McIntosh, Delicious, York Imperial, and Gallia Beauty, reported that "no increase in fruit

color or maturity as a direct result of using 2,4,5-TP sprays was observed on varieties in the McIntosh season or later."

Smock, *et al.*,[21] from experiments conducted in 1951, reported that 2,4,5-TP applied to Early McIntosh at 20 p.p.m. 11 days before harvest "resulted in fruits that were highly significantly softer than the controls" and that had a "more highly developed ground color and surface color."

With McIntosh, they found that an application of 2,4,5-TP at a concentration of 20 p.p.m. 2 weeks before the first harvest date "resulted in softer fruit than the control" and that the "fruit was redder and had a more highly developed ground color." At the second harvest, which was 24 days after spraying, the fruit that had received this treatment showed, as compared with the controls, "an even greater difference in ripeness than at the first date." Their data show that at this picking there was, as compared with the fruit of the first picking, a greater difference between treated and check fruits in firmness and in amount of yellow in the background color.

In neither of these varieties was the degree of maturation at harvest stated. From the data shown on background color, it appears that none of the treated samples was definitely mature and that all the control samples were definitely immature.

Southwick *et al.*[23] conducted experiments with 2,4,5-TP in 1950 and 1951. They reported that in 1950 a concentration of 20 p.p.m. hastened softening in McIntosh, and that the same concentration applied in 1951 to McIntosh in two other orchards produced a similar effect in one and a much less marked effect in the other. The orchard showing the greater effect of the two had darker green foliage, indicative of a higher plane of nitrogen nutrition. Twenty-six days after the treatment, many of the fruits in this orchard had developed water core or cracked on the tree.

An application of the same concentration to Golden Delicious 5 weeks before harvest resulted in definitely softer fruit than the checks, even though their data on background color show that the check fruit was more nearly yellow than the treated fruits — a clear-cut example of a kind of abnormal maturation sometimes induced by 2,4,5-TP in Golden Delicious. 2,4,5-TP applied to Baldwin at a concentration of 20 p.p.m. did not appear to affect maturation.

White,[28] investigating in 1951 the effect of certain combinations of chemicals on Delicious, reported that 10 p.p.m. of 2,4,5-TP, mixed with other chemicals in three combinations, had no appreciable effect on the firmness of the apples by the time they became mature.

Resumé of the Effects of NAA and 2,4,5-TP

McIntosh and Early McIntosh are apparently the only fall-maturing varieties in which NAA has increased the rate of softening. Although no report concerning the effect of NAA on Cortland has been encountered, it seems likely that this variety would respond in the same way, since its texture is similar to that of McIntosh and Early McIntosh.

McIntosh and Early McIntosh are, of all fall-maturing varieties, most often reported to have had their rate of softening or color development increased by 2,4,5-TP, with Golden Delicious, Delicious, and Baldwin being the only other fall-maturing varieties in which a softening effect has been noted. The variable responses that McIntosh makes to 2,4,5-TP can be attributed to such factors as differences in environment, the nutritional status of the trees, the times and conditions when applications were made, and the maturation stages of the apples at harvest.

The ideal way of determining the effects of a preharvest spray on the maturation of apples is to collect samples of immature, mature, and post-mature check fruits and compare their maturation characteristics with those of treated fruits collected on the same dates. If samples can be collected at only one time, they should be collected when the check fruits are mature. The check and treated fruits can then be compared not only to determine the degree by which the maturity date was advanced or retarded by the material but to determine also whether maturation was abnormal — a situation that exists whenever one or more of the characteristics of maturation progress at a rate different from that of the other characteristics. If radical abnormalities occur, as in some of the summer-maturing varieties,[3, 18] they will become obvious while the apples are immature.

If the samples cannot be collected when the check fruits are mature, the degree of maturation of both check and treated samples should be specified so that the reader can determine whether the spray material affected maturation. Most papers fail to specify the degree of maturation of the samples used, which leaves a vital factor of the experiment in doubt.

A statement regarding the degree of maturation at harvest is also of paramount importance because it is positively correlated with the degree of quality within a variety. The well-known consumer preference for high-quality fruit makes it imperative that effects should be measured primarily in terms of quality, of which rate and type of

maturation are the most significant factors. Yet, in spite of these facts, most published reports are quite unspecific about maturation and scarcely ever mention quality.

MATERIALS AND METHODS

The daily rainfall and the daily minimum, maximum, and mean temperatures for September and October — the months during which the experiment reported in this bulletin was conducted — are recorded in Table 1. The mean temperature was 3.5 degrees below normal in September and 2.4 degrees above normal in October, owing primarily to the high temperatures during the first 5 days of the month. Temperature readings made at 7 p.m. on September 11 and 25, at the completion of spray applications, were 73° and 60° F. respectively.

The total rainfall for September was 1.13 inches below the 59-year average, but the 2.13 inches that fell in that month was considered sufficient for normal fruit development. In October 2.76 inches were recorded, slightly more than the normal 2.53 inches. Only 0.70 inch of this fell before sampling was completed, but there seemed to be sufficient moisture for normal maturation.

In September, 19 days were clear or partly clear, and 13 of the 16 days comprising the October sampling period were partly clear to clear; consequently the conditions for the promotion of red color development were good to very good.

The day after each of the two applications of 2,4,5-TP high winds swept the orchard. On September 12 wind velocity reached 20 miles per hour; on September 26, 18 miles per hour. These winds may have had an effect on the amount of fruit that dropped.

The trees. The trees of the three varieties investigated were in their fourteenth growing season in a University orchard at Urbana. All trees were in a state of vigor desirable for commercial orchards and had been well pruned for several years. The Jonathan trees had about three-fourths of a full crop, the Starking trees one-half of a full crop, and the Golden Delicious trees nearly a full crop. Ten trees of Jonathan, 10 of Golden Delicious, and 13 of Starking were used.

The spray material. The formulation of 2,4,5-TP which was introduced in 1951 under the trade name of Color-Set 1004[2] was applied. According to Southwick,[24] this formulation is an amine salt of the material.

Spray application. On September 11 and again on September 25, 2,4,5-TP at a concentration of 20 p.p.m. was applied to 5 Jonathan, 5 Golden Delicious, and 7 Starking trees. The remaining trees — 5 Jonathan, 5 Golden Delicious, and 6 Starking — were used as untreated checks. Spraying was begun at 6 p.m. on each of the two dates to avoid drifting by the wind, which would have occurred earlier in the day. At each application approximately 24 gallons of solution were sprayed on each tree, which left the trees thoroughly drenched.

Sampling. In the afternoon of each of the six sample dates shown in Tables 2 to 4, one-half to two-thirds of a bushel of apples was picked from each tree, the apples being selected from all parts of the tree to represent the average of the tree in size and degree of maturation.

The picked apples were sorted in the orchard to remove those that were defective, misshapen, or otherwise obviously different from the

Table 1. — Temperature and Rainfall During Maturation of Jonathan, Starking, and Golden Delicious Apples, 1951

Day of month	September temperature			Rainfall	October temperature			Rainfall
	Minimum	Maximum	Mean		Minimum	Maximum	Mean	
1	63	75	69	.10	56	83	70	0
2	62	68	65	.01	59	80	70	0
3	60	66	63	0	62	84	73	0
4	50	67	59	0	61	88	74	0
5	53	70	62	.03	65	81	73	0
6	62	72	67	.02	52	61	56	.17
7	52	68	60	0	47	55	51	.53
8	46	63	55	0	40	57	48	0
9	51	75	63	.02	36	60	48	0
10	62	78	70	.64	40	64	52	0
11	57	84	71	0	37	69	53	0
12	62	88	75	.34	44	75	60	0
13	53	75	64	.51	45	70	58	0
14	53	78	66	0	47	74	60	0
15	48	68	58	0	50	78	64	0
16	49	69	59	0	50	80	65	0
17	45	73	59	0	52	81	66	0
18	50	80	65	0	49	79	64	0
19	55	80	68	0	41	56	48	0
20	54	82	68	0	34	63	48	0
21	55	84	69	0	42	78	60	0
22	52	68	60	.10	58	70	64	T[a]
23	45	72	58	0	48	51	50	1.85
24	54	64	59	.05	39	55	47	.02
25	59	69	64	.06	35	64	50	0
26	55	80	68	T[a]	43	69	56	0
27	53	61	57	.22	44	47	46	.13
28	37	58	48	0	40	57	48	0
29	36	63	50	0	37	56	46	.05
30	52	64	58	.03	39	60	50	T[a]
31	..	..	..	...	31	37	34	.01

[a] *T* means a trace of rainfall (less than one-hundredth of an inch).

majority. During the sorting process the apples from all the treated trees of each variety were put into a composite group. The check fruits of each variety were similarly combined. The samples were then stored overnight at 32° F.

The following morning each lot was removed from storage. From each composite sample six separate samples, each consisting of 24 apples, were selected on the basis of uniformity of background color, overlying color, and size. These selected fruits were wiped with damp cloth towels to remove dust and most of the spray residue.

The fruits of five of the six samples were then numbered consecutively with India ink and the weight of each fruit determined on a dial balance graduated in grams, so that the weight loss of the sample as a unit could be accurately determined, even though apples that rotted or otherwise became defective in storage were discarded. Four of these five samples were placed in bushel baskets with liners, pads, and lids, and stored at 32° F. The fifth sample, placed in storage at 32° F. overnight, was worked up the next day for chemical determinations. The sixth sample was used immediately for pressure determinations.

Physical determinations. *Cumulative drop.* On September 12, the day after the first spray application, all apples under the trees were removed. On September 25, drop collections were started and continued at weekly intervals until October 16, when the last samples were picked. Percentages of drop were calculated on the basis of weight rather than number (see Table 2, page 17).

Firmness. The firmness of the apples was measured with a Ballauf pressure tester by the method previously described.[18]

Color. Apples were selected from each composite lot for the spectrophotometric measurement of skin and flesh colors. From the resulting spectral curves the equivalent Munsell color notations were calculated. These notations are expressed as Inter-Society Color Council — National Bureau of Standards color names, commonly referred to as ISCC — NBS color names.[11]

Chemical determinations. The details of sample preparation and analyses were carried out as previously described,[18] except that titratable acidity was determined by diluting 10 milliliters of the expressed juice with 190 milliliters of water and titrating with tenth-normal NaOH to a pH of 7.0, with a rheostatically controlled, motor-driven stirrer providing constant agitation. The results were calculated as percent of malic acid. The pH of the expressed juice was deter-

mined on a 50-milliliter sample with a Beckman glass-electrode meter (see Table 3, page 21).

RESULTS

The results of this investigation are separated into observed and measured effects.

On September 11, several hours *before* the first application of 2,4,5-TP was made, samples were picked from the six lots of trees, those to be sprayed and those reserved for checks. The samples of each variety were kept separate in order to compare them before treatment, so that it could be determined whether later differences were due to 2,4,5-TP. This should be kept in mind in reading Tables 2 to 4.

Observed Effects

The major observed effects are described in Table 2. Other important observed effects that cannot be conveniently included in the table are discussed here.

Cracking. No cracking occurred in any of the Jonathan and Starking apples, but many treated Golden Delicious apples cracked in the cavity about the stem as they approached maturity, and even more cracked as they became post-mature. These cavity cracks were of two kinds: cracks that radiated from near the point of stem attachment at the bottom of the cavity, and circular cracks that began at varying depths in the cavity, usually about halfway down. Some of these latter cracks formed a complete circle, but most of them extended only one-half to two-thirds around the cavity. The skin just above these circular cracks usually pulled away from the flesh and exposed it to rot spores, which caused some rot development before harvest.

Maturation and texture. In Jonathan and Starking, 2,4,5-TP had no detectable effect upon the rate of maturation until after the fruits became mature. In the post-mature samples, picked on October 9, the treated apples of both varieties were less crisp than the check apples (see Table 2). The pressure-test data in Table 2 failed to coincide with the observed differences in texture. The differences in texture between check and treated fruits of Jonathan and Starking were not of commercial importance.

In Golden Delicious the treated fruits had become softer and less crisp than the check fruits at the October 2 picking of immature (M3.5) apples. These differences became greater in the mature and post-mature

Table 2. — Effect of Preharvest Sprays of 2,4,5-TP on Maturation Characteristics and Drop of Jonathan, Starking, and Golden Delicious Apples, 1951

Sample date	Treatment	Degree of maturation	Texture	Varietal flavor	Quality	Pressure in pounds	Cumulative drop percent
			Jonathan				
Sept. 11[a]....	Check	M1.0	Hard, crisp, juicy	None, starchy, "green apple" flavor	Poor (U)*	17.1	...
	Treated	M1.0	Hard, crisp, juicy	None, starchy, "green apple" flavor	Poor (U)	17.8	...
Sept. 18....	Check	M2.0	Hard, crisp, juicy	Little, starchy	Fair (U)	16.3	...
	Treated	M2.0	Hard, crisp, juicy	Little, starchy	Fair (U)	16.6	...
Sept. 25....	Check	M3.0	Hard, crisp, juicy	Moderate	Good to very good (A)*	16.5	5.9
	Treated	M3.0	Hard, crisp, juicy	Moderate	Good to very good (A)	16.2	4.5
Oct. 2.....	Check	M4.0	Firm, crisp, juicy	Abundant	Excellent (S)*	15.9	9.9
	Treated	M4.0	Firm, crisp, juicy	Moderate to abundant	Very good to excellent (S)	15.5	6.1
Oct. 9.....	Check	M4.5	Firm, moderate to crisp, juicy	Abundant	Very good to excellent (S)	13.5	28.9
	Treated	M4.5	Firm, moderately crisp, juicy	Moderate to abundant	Very good (S)	13.6	7.4
			Starking				
Sept. 11[a]....	Check	M1.0	Hard, crisp, juicy	None, starchy, "green apple" flavor	Poor (U)	17.6	...
	Treated	M1.0	Hard, crisp, juicy	None, starchy, "green apple" flavor	Poor (U)	18.2	...
Sept. 18....	Check	M2.0	Hard, crisp, juicy	None, starchy	Poor to fair (U)	17.1	...
	Treated	M2.0	Hard, crisp, juicy	None, starchy	Poor to fair (U)	16.5	...
Sept. 25....	Check	M3.0	Hard, crisp, juicy	Little, starchy	Fair (U)	17.7	8.6
	Treated	M3.0	Hard, crisp, juicy	Little, starchy	Fair (U)	17.0	5.4
Oct. 2.....	Check	M4.0	Hard, crisp, juicy	Moderate	Good (A)	16.4	18.6
	Treated	M4.0	Hard, crisp, juicy	Moderate minus	Good (A)	16.2	7.1
Oct. 9.....	Check	M4.5	Firm, crisp, juicy	Moderate to abundant	Very good (S)	14.8	45.5
	Treated	M4.5	Firm, moderate to crisp, juicy	Moderate	Good (A)	14.8	10.6
			Golden Delicious				
Sept. 11[a]....	Check	M1.0	Hard, tough, very juicy	None, starchy, "green apple" flavor	Poor (U)	16.8	...
	Treated	M1.0	Hard, tough, very juicy	None, starchy, "green apple" flavor	Poor (U)	16.3	...
Sept. 18....	Check	M2.0	Hard, crisp, juicy	Little, starchy	Poor (U)	18.5	...
	Treated	M2.0	Hard, crisp, juicy	Little, starchy	Poor (U)	17.2	...
Sept. 25....	Check	M3.0	Hard, crisp, juicy	Little to moderate starchy	Fair (U)	15.7	3.4
	Treated	M3.0	Hard, crisp, juicy	Little to moderate, starchy	Fair (U)	16.4	2.4
Oct. 2.....	Check	M3.5	Firm, crisp, juicy	Moderate	Good (A)	16.6	5.7
	Treated	M3.5	Firm, moderately crisp, juicy	Moderate minus	Fair (U)	15.5	3.6
Oct. 9.....	Check	M4.0	Firm, crisp, juicy	Moderate to abundant	Very good (S)	14.7	17.6
	Treated	M4.0	Firm, moderately crisp, moderately juicy	Moderate	Good (A)	11.9	4.5
Oct. 16.....	Check	M4.5	Firm, moderate to crisp, juicy	Moderate to abundant	Very good (S)	13.7	21.7
	Treated	M4.5	Moderately firm, semi-mealy, moderately juicy	Moderate	Good (A)	10.0	5.1

[a] See page 16 for an explanation of this sample.
* *U*, *A*, and *S* signify unacceptable, acceptable, and satisfactory respectively.

samples. The differences in pressure between check and treated fruits in these last three pickings of Golden Delicious were correlated with the observed differences in texture. The difference in texture between check and treated fruits was of commercial importance. The greater rate of softening in the treated fruits of this variety, starting at least one week before the apples reached maturity, became rapid enough to make the texture undesirable by the time they became mature, and worse as the apples progressed into post-maturity.

Flavor. As shown in Table 2, the check fruits of all three varieties had at maturity a higher flavor than the treated fruits, which reflected a differential development of varietal aroma. This difference in flavor was not great enough to be of commercial importance for Jonathan and Starking, but the higher flavor of the mature and post-mature Golden Delicious check samples was definitely of commercial importance.

Quality. *Jonathan.* As shown in Table 2, 2,4,5-TP did not affect quality except in the mature and post-mature sample collections. The difference between check and treated apples was not of sufficient commercial importance to prevent both from being rated satisfactory. However, the difference would be noticed by consumers of discriminating flavor perception, particularly if Jonathan was their favorite apple variety. The slightly lower quality of the treated fruits indicates that 2,4,5-TP had a deleterious effect on flavor.

Starking. A difference in quality existed only in the post-mature samples collected on October 9. The lower quality of the treated fruits might not be readily noticed, except by the consumer familiar with the flavor variations of Starking. Both the check and treated October 2 samples and the treated October 9 sample were rated acceptable, whereas the October 9 check sample was the only one that could be rated satisfactory (see Table 2).

Golden Delicious. In the last three sample collections the treated fruits were lower in quality than the checks. Since lower quality in the treated fruits was noted for the first time in the immature October 2 sample, the deleterious effect of 2,4,5-TP on quality must have become active some time before that date. This shows that Golden Delicious reacted more to 2,4,5-TP than Jonathan or Starking, for in both of these latter varieties deficient quality in the treated fruits was not evident until maturity. The lower quality of the treated Golden Delicious fruits was due to the combination of less crispness and deficient aroma.

The check fruits in the October 9 and October 16 Golden Delicious samples were rated satisfactory, even though none of them had the degree of quality frequently found in mature Golden Delicious. The rating of acceptable was given to the check fruits in the October 2 samples and to the treated fruits in the October 9 and October 16 samples (see Table 2).

Measured Effects

Drop. The cumulative drop in percent of total weight of yield is shown in Table 2. 2,4,5-TP was quite effective in reducing drop, particularly as the apples approached maturity and thereafter.

Color. Some trade names for 2,4,5-TP, such as Stikol, Color-Set, and others, may give the impression that this chemical can increase the rate of development of the desirable red and yellow colors in apples. The spectrophotometric measurements made at each sample date of the skin colors of representative Jonathan and Starking apples failed to show that 2,4,5-TP increased red color, either in amount or intensity. In a small percentage of the mature treated fruits of these varieties, the background color was moderate yellow rather than the normal pale yellow. As the sprayed Jonathan and Starking fruits became post-mature, more of them developed this moderate yellow background color, but the percentage remained relatively small.

The spectrophotometric measurements also showed that by the time the treated Golden Delicious apples reached maturity, many of them had developed, as compared with the normal skin color of mature Golden Delicious, a skin color characterized by a lower yellow hue number (closer to yellow red), a lower value number (darker), and sometimes a higher chroma number (brighter).[18a] This color also occurred as patches of various sizes in the skin of the immature fruits. As the treated Golden Delicious apples became post-mature, nearly all of them developed this color. There was no evidence that 2,4,5-TP induced a blush on Golden Delicious apples.

In none of the three varieties was the flesh color of treated fruits different from that of their corresponding check fruits. In Jonathan, the flesh color of the September 11 and September 18 samples was pale greenish yellow. In the later samples it was pale yellow. In Starking, the flesh color of the September 11 and September 18 samples was pale greenish yellow. In the September 25 samples it was pale greenish

[a] In the publication cited, these and other color terms are explained in detail.

yellow or pale yellow, and in the later samples, pale yellow. In Golden Delicious, the September 11 and September 18 samples had a pale greenish yellow flesh color. In the September 25 samples the flesh color was usually pale yellow. All the later samples had a pale yellow flesh color.

In each of the three varieties the hue number of the flesh became progressively lower (closer to yellow red) with increasing maturation, even though the flesh colors of Jonathan and Starking at the last two sample dates and of Golden Delicious at the last three sample dates were classified as pale yellow because of the rather wide range in hue numbers in the pale-yellow designation in the ISCC-NBS color names.[11]

Firmness. The pressure tester unfortunately gives only a rough measure of fruit texture, and from the data in Table 2 it would appear that there was no consistent difference in firmness between either Jonathan or Starking check and treated samples. Actually, the texture difference in the last sample collections of each variety was readily detectable by cutting or chewing.

The pressure differences between check and treated fruits in the last three Golden Delicious sample collections, together with the observed differences in texture, show conclusively that 2,4,5-TP had a softening effect on this variety (Table 2). Since Golden Delicious frequently passes from a crisp, firm texture at maturity to a semi-mealy or mealy texture in one to two weeks after maturity, any spray material that hastens this process, as 2,4,5-TP did, is undesirable, even though its other effects, such as inhibiting drop, may be quite desirable.

Composition of the juice. *Soluble solids percentage.* Table 3 shows that there was no consistent difference in the percentage of soluble solids between the check and treated fruits of any of the three varieties. Starking and Golden Delicious showed a definite upward trend as the apples matured. This trend coincided with the higher quality of the mature and post-mature samples. The lack of such a trend in the Jonathans is not unusual.

Acid percentage. The differences shown in Table 3 between check and treated Jonathans in percentage of titratable acidity were not important; only the most taste-conscious consumers would have been able to detect them. The decreasing percentage in acid as Jonathan matured was usual.[15]

The differences in this respect between Starking check and treated samples were also insignificant. The low acid values in the October 2 samples were similar to those usually encountered in Starking. The

higher values in the October 9 samples may have been due in part, if not entirely, to the decrease in temperature from October 5 to 9, since acidity is known to be higher during cool weather.

The differences in acid content between Golden Delicious check and treated fruits were significant only in the last two samples, and they were consistent with the observed deleterious effects that 2,4,5-TP had on Golden Delicious quality. All the acid percentages shown for Golden Delicious were much higher than those previously found for Golden Delicious fruits at comparable stages of maturation. Information obtained subsequent to this investigation shows that this variety fluctuates widely in acid content at any specific stage of maturation.[15]

Hydrogen-ion concentration. The pH of these varieties was roughly correlated negatively with the titratable acidity; consequently, a significant difference between check and treated samples occurred only in the last two Golden Delicious sample collections.

Soluble solids–acid ratio. This ratio was calculated from the soluble solids and titratable acidity values that were determined on the expressed juice (see Table 3). It is sometimes used as an indicator of the degree of quality of maturing apples.

The differences between Jonathan check and treated samples were not significant. The ratio failed to indicate the differences in quality

Table 3. — Changes in Composition of Expressed Juice During Maturation of Jonathan, Starking, and Golden Delicious Apples, 1951

Date picked	Percent of soluble solids		Percent of malic acid		pH		Soluble solids-acid ratio	
	Check	Treated	Check	Treated	Check	Treated	Check	Treated
Jonathan								
Sept. 11[a]	12.6	12.8	.85	.83	3.30	3.30	14.82	15.42
Sept. 18	13.0	12.3	.85	.82	3.31	3.32	15.29	15.00
Sept. 25	13.6	13.1	.78	.75	3.30	3.30	17.44	17.47
Oct. 2	13.4	13.1	.67	.61	3.34	3.36	20.00	21.48
Oct. 9	13.2	12.8	.59	.57	3.41	3.44	22.37	22.46
Starking								
Sept. 11[a]	10.5	10.4	.28	.30	3.80	3.80	37.50	34.67
Sept. 18	11.2	10.8	.32	.30	3.95	4.00	35.00	36.00
Sept. 25	12.5	12.1	.32	.30	3.96	3.95	39.06	40.33
Oct. 2	12.6	12.7	.21	.19	3.96	3.98	60.00	66.84
Oct. 9	13.4	13.1	.28	.27	4.00	4.00	47.86	48.52
Golden Delicious								
Sept. 11[a]	12.4	12.4	.56	.58	3.38	3.35	22.14	21.38
Sept. 18	13.1	12.1	.59	.55	3.39	3.41	22.20	22.00
Sept. 25	14.3	14.0	.56	.55	3.40	3.43	25.54	25.45
Oct. 2	15.2	15.0	.52	.49	3.40	3.45	29.23	30.61
Oct. 9	16.9	16.1	.69	.55	3.32	3.47	24.49	29.27
Oct. 16	16.5	16.1	.66	.47	3.40	3.57	25.00	34.26

[a] See page 16 for an explanation of this sample.

between check and treated fruits shown in Table 2 for the last two sample collections.

The data on Starking also showed no important difference between check and treated fruits. Here, as in Jonathan, the quality difference shown in Table 2 between check and treated fruits in the last sample is not indicated by the ratios.

The high acid values of the October 9 Starking samples, even though accompanied by increases in soluble solids, caused a marked reduction in the ratio number in comparison with the October 2 samples. Reliance on ratio numbers alone would indicate a quite definite decrease in quality in the October 9 samples, but Table 2 shows that this was not the case.

Table 3 shows that the treated Golden Delicious fruits had higher ratios than the check fruits in the last two samples. The ratio numbers here would indicate higher quality in the treated fruits, whereas just the opposite was true. This discrepancy is due to the lower acid percentages in the treated fruits in the last two samples.

Composition of the flesh. *Sugars.* Table 4 shows the changes in sugar percentages.

In Jonathan none of the three sugars showed a consistent trend nor, consequently, did total sugars. Neither was there a consistent difference between Jonathan check and treated fruits. The failure of the sugars to increase significantly during maturation shows that the increases in quality noted in Table 2 were due primarily to decreases in acidity and increases in aromatic compounds.

In Starking there was also no significant difference between check and treated fruits. The upward trend of each of the sugars is usual for Starking during maturation.[15] The more than 100-percent increase in sucrose in both the check and treated samples emphasizes the low quality of the early sample collections and helps to explain the much higher quality of the last two sample collections.

In Golden Delicious only the last sample collection showed enough difference in sugar content between check and treated fruit to affect quality, and even here the difference in quality noted in Table 2 was probably due mostly to differences in texture and aromatic compounds. The very significant increases in sucrose and total sugars during maturation help to account for the low quality of the early sample collections.

Dry matter. The dry-matter percentages of the check samples were consistently higher than those of the treated samples in all three

varieties (see Table 4). It is doubtful that differences of the magnitude shown would have any important effect on texture or flavor, except possibly in the last two sample collections of Golden Delicious. Here the lower dry-matter content of the treated samples was associated with decreased crispness and juiciness of the flesh and with lower quality.

Summary of the Effects of 2,4,5-TP on Maturation

The effects of 2,4,5-TP on the maturation of these three varieties can be summarized as follows:

1. 2,4,5-TP was very effective as a drop inhibitor, particularly as the apples reached and passed maturity.

2. Jonathan and Starking showed no measurable increase from 2,4,5-TP either in amount or intensity of red color development. Mature, post-mature, and, occasionally, immature Golden Delicious fruits developed a yellow background color that was of lower hue (nearer yellow-red) and lower value (darker) than normal; and this color was accompanied by softer-than-normal texture and deficient Golden Delicious flavor.

3. In Jonathan and Starking the treated fruits had a texture less crisp than that of the check fruits after both passed maturity, but not before.

Table 4. — Changes in Fresh-Weight Percentages of Sugars and Dry Matter During Maturation of Jonathan, Starking, and Golden Delicious Apples, 1951

Date picked	Dextrose		Levulose		Sucrose		Total sugars		Dry matter	
	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated
Jonathan										
Sept. 11[a]	1.70	1.77	5.84	5.82	3.09	3.38	10.63	10.97	16.05	16.35
Sept. 18	1.63	1.54	6.11	5.96	3.16	3.22	10.90	10.72	16.45	15.95
Sept. 25	1.70	1.68	6.20	5.78	3.79	3.82	11.69	11.28	16.80	16.25
Oct. 2	1.49	1.50	5.97	5.98	3.61	3.59	11.07	11.07	16.50	15.90
Oct. 9	1.61	1.62	5.95	5.82	3.66	3.44	11.22	10.88	15.90	15.40
Starking										
Sept. 11[a]	1.42	1.44	5.72	5.53	1.73	1.78	8.87	8.74	15.80	15.60
Sept. 18	1.39	1.42	5.86	5.67	2.39	2.30	9.64	9.39	16.20	15.40
Sept. 25	1.51	1.54	5.90	5.80	3.19	3.24	10.60	10.58	16.80	16.25
Oct. 2	1.77	1.63	6.04	6.16	3.51	3.74	11.32	11.53	16.40	15.75
Oct. 9	1.64	1.65	5.92	5.84	3.78	3.83	11.34	11.32	16.95	16.30
Golden Delicious										
Sept. 11[a]	1.13	1.18	6.18	6.09	3.17	3.19	10.48	10.46	16.80	16.65
Sept. 18	1.20	1.26	6.52	6.20	3.67	3.44	11.39	10.90	17.75	16.45
Sept. 25	1.24	1.20	7.01	6.46	4.72	4.71	12.97	12.37	18.40	17.85
Oct. 2	1.34	1.32	7.31	6.81	4.85	5.23	13.50	13.36	18.75	18.35
Oct. 9	1.49	1.27	6.95	6.83	5.56	5.60	14.00	13.70	20.55	18.85
Oct. 16	1.41	1.44	7.13	7.00	6.34	5.46	14.94	13.90	19.65	18.85

[a] See page 16 for an explanation of this sample.

4. In Golden Delicious the treated fruits became less firm and less crisp than the check fruits as they approached maturity. In the mature and post-mature fruits this difference was great enough to constitute abnormal maturation, and was accompanied by serious cavity cracking.

5. The concentration of acid, sugars, and dry matter was not significantly affected by 2,4,5-TP, except that in the mature and post-mature Golden Delicious samples the acidity and dry-matter percentages were significantly lower than the checks.

6. Owing to 2,4,5-TP, the quality of mature and post-mature Jonathan and Starking fruits was lower than normal because of decreased crispness or deficient varietal flavor, or both. Similarly, the quality of nearly mature, mature, and post-mature Golden Delicious apples was lower than normal because of softer texture and deficient Golden Delicious flavor.

EVALUATION OF RESULTS

In considering whether a new preharvest spray should be adopted by fruit growers, the advantages and disadvantages relative to yield and quality should be determined because the greatest economic returns are obtained from high yields of high-quality fruit. It is on this basis that 2,4,5-TP as a preharvest spray for fall-maturing apples is evaluated below.

Effects of 2,4,5-TP on Yield

Direct effect. A preharvest spray can directly affect yield only by stimulating the growth of the fruit so that it is larger at maturity. There seems to be no evidence that apples sprayed with 2,4,5-TP are larger at maturity than check fruits. On the contrary, there is some evidence that applying 2,4,5-TP to apples 8 to 10 weeks before the time they usually reach maturity may result in fruit of reduced size.[1, 15]

Indirect effects. *Drop.* A reduction in the number of dropped apples increases the amount of marketable fruit in the higher grades. This is an important economic advantage, provided that drop reduction is achieved without adverse effects. 2,4,5-TP does reduce drop — not always more effectively than NAA, however[17] — but from the use of 2,4,5-TP on some fall-maturing varieties such as Golden Delicious there is the probability of the mature fruit having softer texture. Such a probability does not occur from the use of NAA. It should be noted,

however, that 2,4,5-TP was more effective than NAA on Turley: it controlled drop very effectively without adverse effects on the fruit.[17]

Cracking. Cracking may also seriously reduce the amount of marketable fruit in the higher grades because the largest apples are those most prone to crack. The natural tendency of Golden Delicious to crack in the cavity has been accentuated by 2,4,5-TP; consequently, this material should not be used on Golden Delicious, except possibly in certain environments in which this variety does not normally crack.

Effects of 2,4,5-TP on Quality

As was pointed out previously, the effect of any treatment on apple quality can be properly evaluated only by comparing fruits from that treatment with check fruits at the same stage of maturation. The use of mature fruit for this comparison is highly desirable for two reasons: consumers prefer mature fruit and pomologists gain a fuller understanding of the physiological responses that the fruit makes to the treatment. If, however, the treatment is found to cause markedly abnormal maturation, as 2,4,5-TP did in some summer-maturing varieties,[18] that alone is sufficient to condemn it, even though no comparison of mature fruit can be made.

Texture. The adverse effect that 2,4,5-TP had on the texture of Jonathan and Starking was apparent only after the apples had passed maturity (see Table 2), but was not of commercial significance. In Golden Delicious, the softer texture caused by 2,4,5-TP became evident as the apples approached maturity, and this softer texture was accentuated as the apples progressed into post-maturity. This effect, which in Golden Delicious was accompanied by decreased quality, can seriously reduce economic returns.

Later observations, made during the abnormally hot and dry maturation season of 1953,[a] showed that 2,4,5-TP, applied twice at concentrations of 20 p.p.m., did not increase the rate of softening in Jonathan, Delicious, Starking, Red Rome, Winesap, and Stayman to a commercially important extent, but that it did have the same effect on Golden

[a] In 1953 the mean temperature in September was 2.2 degrees above normal. Several days near the beginning and end of that month had temperatures above 90. The mean temperature in October was 5.8 degrees above normal, with temperatures near 90 during the harvest of Red Rome, Stayman, and Winesap. Precipitation in September was 2.67 inches below normal, with only 0.59 inch of relatively ineffective rainfall. In October, rainfall of 1.71 inches was 0.84 inch below normal, but 1.40 inches of the total fell after harvest was completed.

Delicious that has been described in this bulletin. 2,4,5-TP decreased keepability only in Stayman and Golden Delicious. It seems then that 2,4,5-TP can be safely used on most fall-maturing varieties grown extensively in Illinois; however, there may be conditions still unknown under which one or more of these varieties might soften seriously. The fact that Illinois growers, to control the drop of most fall-maturing varieties, make the first application of NAA 5 to 6 weeks before the apples are mature, and then make a second, third, and sometimes a fourth application without apparently affecting the rate of maturation in these varieties, indicates that 2,4,5-TP has a potentially greater softening effect than NAA.

Flavor. Flavor being the combination of taste and aroma, any change that affects the concentration of sugars and acids or the development of characterististic apple and varietal aromas automatically affects flavor. Since flavor is correlated with maturation, abnormal maturation may be accompanied by deficient flavor. In this investigation whenever softer-than-normal texture occurred, it was accompanied by deficient apple and varietal aroma.

In this respect 2,4,5-TP compares unfavorably with NAA, which does not seem to affect flavor. In Jonathan apples, for example, that were given three applications of NAA on September 19, October 1, and October 11, 1947, and that were harvested on November 12, 39 days after the apples had become mature, flavor increased throughout the period and was in no way noticeably different from the flavor of the check fruits.[14]

Color. Color is considered in this discussion of quality because, in addition to being correlated with maturation, it has a strong psychological appeal to customers and is therefore an economic asset to growers. The fact that consumers will usually pay more for apples that are nearly covered with a bright-red color or that are predominantly yellow has caused apple growers to use any material that promises to promote such colors on their apples. Stikol, Color-Set, and other trade names for 2,4,5-TP seem to have been coined with this in mind, since the power to induce color is implied in the names.

It has been shown that 2,4,5-TP increased the rate of red color development in some summer-maturing varieties, but only at the expense of abnormal maturation, as manifested by much softer texture than normal and markedly deficient aroma.[18] In the red-colored fall-maturing varieties that are commercially important in Illinois, the results obtained during the 1950, 1951, 1952, and 1953 seasons failed to

show that 2,4,5-TP increased red color either in amount or intensity. In the yellow-colored varieties 2,4,5-TP induced a more noticeable color, but the effect was of doubtful value since it appeared deadlike and, to some observers, less attractive than the normal color of mature yellow apples. More important, by the time this color became evident, the texture of the apple had become softer than normal, even in the case of immature fruit.

In Illinois, at least, there seems to be little point in using sprays to induce color. All the fall-maturing varieties grown in Illinois develop satisfactory red and yellow colors if the trees are kept in a desirable plane of nutrition by proper fertilization, pruning, thinning, and pest control, and if the apples are not harvested before they near maturity.

RECOMMENDATIONS

The following are the recommendations for the use of 2,4,5-TP as a preharvest spray on fall-maturing apple varieties in Illinois:

1. If NAA has proved satisfactory, its use should be continued in preference to 2,4,5-TP.

2. Before a grower uses 2,4,5-TP extensively, he should apply it experimentally to a few trees of each variety to determine the results that can be expected under the conditions prevailing in his orchard.

3. If the apples are to be consumed soon after harvest, 2,4,5-TP can be used on most fall-maturing varieties, but care must be taken to harvest Golden Delicious and varieties with similar texture shortly before they reach maturity.

4. If the apples are to be stored, 2,4,5-TP probably will not affect keepability adversely when used on Jonathan, Jonared, Delicious, Starking, Red Roma, Gallia, Turley, and Winesap if they are harvested at or shortly before they reach maturity. Its use is likely to cause inferior keepability in Golden Delicious and varieties with similar texture.[15, 19]

5. When 2,4,5-TP is used on Golden Delicious, decreased firmness, stem-end cracking, and deficient flavor may be expected. These effects are less likely to occur when 2,4,5-TP is used on Golden Delicious trees that are moderately vigorous and produce medium-sized apples that at maturity are normally hard, crisp, and juicy. However, since drop of Golden Delicious apples can be controlled satisfactorily with NAA

there seems to be no reason for introducing the risk of deleterious effects from the use of 2,4,5-TP on this variety.

6. No appreciably earlier appearance of red color or significant increase in the amount or intensity of red color can be expected from the use of 2,4,5-TP on the red fall-maturing varieties or on the red sports.

7. Though 2,4,5-TP induced a quite noticeable yellow color on the yellow fall-maturing varieties, this effect was of little or no advantage, since it was usually accompanied by decreased firmness and deficient flavor.

8. There has been no evidence that 2,4,5-TP induced the development of a blush on the yellow fall-maturing varieties.

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Two other Illinois Agricultural Experiment Station Bulletins report investigations similar to the one reported here. Those publications are:

Effect of Preharvest Sprays of 2,4,5-Trichlorophenoxypropionic Acid Upon the Maturation of Fruits of Important Summer-Maturing Apple Varieties. Bulletin 588. By Richard V. Lott and Robert R. Rice. 32p. 1955.

Effect of Preharvest Sprays of 2,4,5-Trichlorophenoxypropionic Acid Upon the Ripening of Jonathan, Starking, and Golden Delicious Apples. Bulletin 590. By Richard V. Lott and Robert R. Rice. 31p. 1955.

3M—6-55—57492