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## A STANDARDIZED METHOD FOR COLLECTING APPLE PRESSURE TEST DATA

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## Introduction

This bulletin outlines a standardized method for collecting apple pressure test data. In the first section we discuss replication and sample size. In the next sections we present information from many sources to illustrate several factors that may influence pressure test readings. The bulletin concludes with a brief "how-to" summary of the important points previously reported in greater detail.

The two types of instruments in widespread use today are the Magness-Taylor pressure tester and the more recently introduced Effegi fruit-tester. When properly calibrated, the two types of instruments generate comparable data. In comparison with the Magness-Taylor instrument, the Effegi tester is more easily calibrated, more compact (and therefore easier to carry into the field), faster to operate, and less subject to clogging with fruit juice.

## Replication and Sample Size

Fruit from individual trees may be kept separated so that trees can be used for replication of each treatment. If trees are used as separate replicates for storage as well as orchard experiments, the within-replicate variation is reduced, minimizing the number of replicates needed. When trees cannot be used as replicates (marketing and some storage studies) apples may be selected at random from different containers to insure that the sample is representative of the entire lot of fruit. The recommended minimum number of fruits per replicate, for 3, 4, 5, and 6 replicates with 1 and 2 tests per fruit are shown in table 1.

## Sample Collection

The most important factors in sample collection that might influence pressure test values are discussed in this section.

**Nitrogen Status of the Tree.** A typical effect of nitrogen fertilization on fruit firmness is shown in table 2. Heavy nitrogen fertilization resulted in softer fruit at harvest and after removal from storage in January. Unless nitrogen status is a desirable variable, trees with comparable vigor should be selected for the experiment. Length of terminal growth, fruit size and color, and leaf color may be used to judge levels of tree vigor.

**Fruit Position in Tree.** Fruit position per se probably has no significant influence on pressure test values if the trees are small and therefore have only one light zone. Since fruit trees usually have at least two light zones and

Table 1. Recommended minimum sample size for pressure tests

Replicates per treatment	Pressure tests per fruit	Fruits per replicate	Fruits per treatment	Pressure tests per treatment
3	1	40	120	120
3	2	20	60	120
4	1	30	120	120
4	2	15	60	120
5	1	20	100	100
5	2	10	50	100
6	1	15	90	90
6	2	8	48	96

Table 2. Effect of N fertilization on firmness of Golden Delicious apples (New York tests)

$NH_4NO_3$ per tree	Harvest date 1975				
	Sept 19	Sept 27	Oct 3	Oct 11	Mean
kg (lb)	kg (lb)	kg (lb)	kg (lb)	kg (lb)	kg (lb)
	At harvest				
0 (0)	7.95 (17.5)	7.67 (16.9)	6.89 (15.2)	6.58 (14.5)	7.26a (16.0)
0.45 (1)	6.67 (14.7)	6.67 (14.7)	6.58 (14.5)	6.08 (13.4)	6.49b (14.3)
1.36 (3)	6.22 (13.7)	6.08 (13.4)	5.99 (13.2)	5.80 (12.8)	6.04c (13.3)
Mean*	6.94a (15.3)	6.80a (15.0)	6.49b (14.3)	6.17c (13.6)	
	January 1976				
0 (0)	5.13 (11.3)	4.95 (10.9)	5.04 (11.1)	4.86 (10.7)	4.99a (11.0)
0.45 (1)	4.59 (10.1)	4.54 (10.0)	4.44 ( 9.8)	4.44 ( 9.8)	4.49b ( 9.9)
1.36 (3)	4.40 ( 9.7)	3.95 ( 8.7)	4.08 ( 9.0)	3.95 ( 8.7)	4.08c ( 9.0)
Mean*	4.72a (10.4)	4.49a ( 9.9)	4.54a (10.0)	4.40a ( 9.7)	

\*Mean separation by Duncan's multiple range test, 5% level.

since light zones influence pressure test values (fig. 1), position of the fruit in the tree must be considered when collecting a sample for pressure testing or for subsequent use in storage trials.

Care must be taken that fruits from an exposed position in one tree are not compared with fruits from other positions in a second tree. Although it is acceptable to limit sample collection to fruits in exposed positions, it is more desirable to sample fruits from several positions to observe the possible range in responses to a treatment. If all the apples are picked from a large limb, the distribution of apples in the various light zones will probably be roughly comparable to the distribution of apples in the various light zones of the entire tree. When single limbs, rather than entire trees, are harvested, care must be taken to either standardize or randomize the tree

quadrant (north, east, south, or west).

In storage experiments the fruit should be composited from each single large limb, entire tree sector, whole tree or group of trees so that representative fruits are submitted as a replicate to each of the storage treatments.

**Watercore.** The development of watercore frequently increases the flesh firmness of apples (fig. 2). Orchard treatments that hasten ripening may also increase watercore intensity. Thus, firmness evaluations may be misleading if watercore intensity has not been evaluated. For example, ethephon [(2-chloroethyl) phosphonic acid] tree sprays hasten ripening, but the treated apples may be more firm than control fruit because ethephon also increases watercore. Therefore, if watercore is present in apples when they are pressure tested, the pressure tested apples should be cut and scored for watercore intensity. If

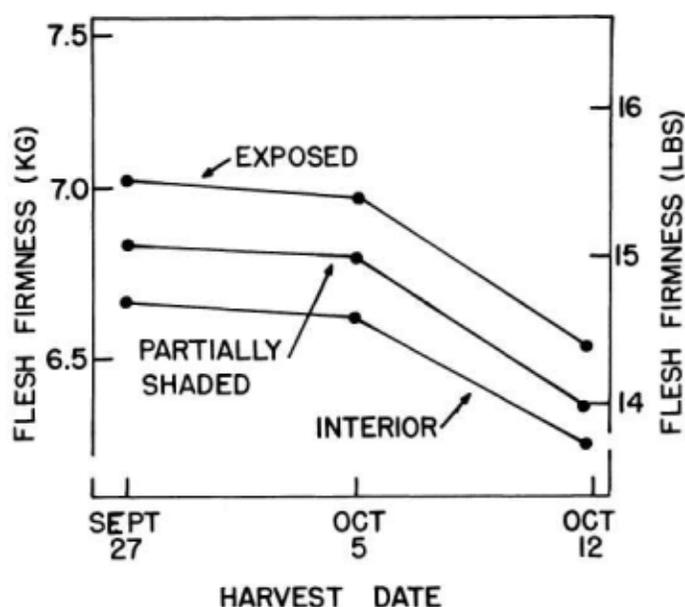


Figure 1. Harvest firmness of apples picked from exposed, partially shaded, and interior zones of large mature Jonathan trees (Michigan tests).

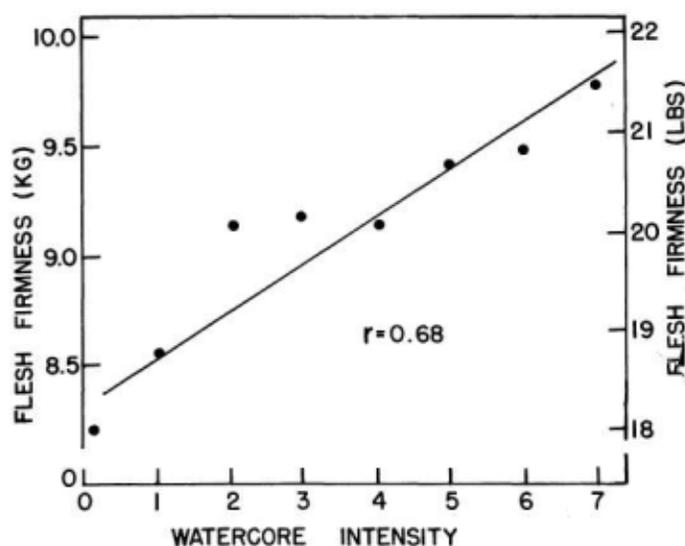


Figure 2. Relationship between visual score of watercore intensity and firmness of Delicious apples at harvest. (1-3=slight, 4-6=moderate, 7=severe watercore) (Massachusetts tests).

Table 3. Relationship between fruit diameter and firmness

Variety	State	Fruit diameter — cm (inches)							
		5.7 (2¼)		6.4 (2½)		7.0 (2¾)		7.6 (3)	
		kg	(lb)	kg	(lb)	kg	(lb)	kg	(lb)
McIntosh	NY	5.80a	(12.8)	5.67a	(12.5)	5.67a	(12.5)	5.13b	(11.3)
Empire	NY	7.07a	(15.6)	6.63b	(14.6)	6.63b	(14.6)	6.49b	(14.3)
Delicious	NY	7.71a	(17.0)	7.26b	(16.0)	6.98c	(15.4)	5.53d	(12.2)
Delicious	VA			7.80a	(17.2)	7.35b	(16.2)	6.89c	(15.2)
Stayman	VA			7.12a	(15.7)	6.63b	(14.6)		
Stayman	VA					7.21a	(15.9)	6.80b	(15.0)
Winesap	VA			8.87a	(19.5)	8.40b	(18.5)		
Winesap	VA					8.73a	(19.2)	8.35b	(18.4)

Note: Mean separation in rows by Duncan's multiple range test, 5% level.

it is found that a treatment increases the intensity of watercore, pressure test values should not be used to evaluate ripening changes in the fruits.

**Fruit Diameter.** The relation between fruit diameter and firmness is presented in table 3. Large apples are usually softer than small apples. Mean pressure test values can easily be influenced by selecting fruits of different diameters for testing. Therefore, the operator should estimate the average diameter of apples in a replicate and then select fruits with a maximum range in diameter of  $\frac{1}{4}$  inch for pressure testing. If there is a fruit size response to an orchard treatment, the average diameter of the pressure tested fruits should be recorded.

**Fruit Temperature.** Warm apples frequently are softer than comparable cold apples (table 4). Therefore, when comparative pressure test data are collected, all fruits should be the same temperature. If fruits are pressure tested immediately after removal from storage, care should be taken to insure that some fruits have not warmed up during the period between storage removal and testing.

If apples are removed from storage and warmed to room temperature before testing, care should be taken that all the fruits have reached room temperature. The data in table 5 may be used as a guide for the length of the period required for warming apples.

Table 4. *Relation of fruit temperature and firmness for three apple varieties (New York tests)*

Variety	Fruit temperature when tested		
	2°C (36°F)	13°C (55°F)	21°C (70°F)
	firmness—kg (lb)		
R. I. Greening	6.13 (13.5)	5.99 (13.2)	5.67 (12.5)
Idared	6.76 (14.9)	6.44 (14.2)	6.22 (13.7)
Rome	7.44 (16.4)	6.72 (14.8)	6.58 (14.5)
Average	6.76 (14.9)	6.40 (14.1)	6.17 (13.6)

Table 5. *Warming times for apples removed from storage and held in still air in a 20°C (68°F) laboratory (New York tests)*

Location of test apples	Approximate time to raise core temperatures 17°C (30°F) from 0°C (32°F) storage temperature
	hours
Singly on laboratory table	8
Center of single bushel box	22
Center of 18-bushel bin	36
Center of 3x3x3 stack of 27 bushel boxes — spaced 15 cm (6 inches) between vertical stacks 3 boxes high	48
Center of 3x3x3 stack of 27 bushel boxes — tightly stacked	92

## Pressure Tester Calibration

Since both types of pressure tester instruments occasionally lose calibration, they should be checked each day before use. Checking calibration takes about 30 seconds. The first few readings are often higher than subsequent readings if the instrument is not "loosened-up" before the calibration check and before starting the actual tests. Therefore, before use and before the calibration check, work the plunger in and out about a dozen times.

Hold the tester in a vertical position. Place the tip onto the pan of a scale (preferably not a spring scale). Press down slowly on the pressure tester until the scale registers a weight close to the firmness levels you anticipate for the subsequent pressure tests. Read the pressure tester. Repeat several times until you can establish that the instrument is properly calibrated; if not, establish the amount it is reading too high or too low. If the instrument is not in calibration, proceed as outlined below.

**Magness-Taylor Pressure Tester.** Remove the plunger assembly from the barrel of the instrument. Remove the bolt and washers from the end of the plunger assembly. Pull the plunger and spring out of the metal cylinder, then shake the washers out of the cylinder. To make the instrument read higher, move washers from outside to inside the metal cylinder. To make the instrument read lower, move washers from inside to outside the metal cylinder. Reassemble and recheck for calibration.

**Effegi Fruit Tester.** Remove the plunger assembly by unscrewing the chrome guide nut. To make the instrument read higher, insert washers between the chrome guide nut and the stationary brass guide on the plunger shaft. To make the instrument read lower, insert the washers between the spring and the stationary brass guide. The instrument reads even lower if the washers are located above the spring. Reassemble and recheck for calibration.

If the Effegi indicator needle does not stop or does not release properly, clean the case in the area of the release button hole, remove the plunger assembly, and then lubricate the inside of the instrument with a short burst from an aerosol lubricant.

## Sample Preparation

**Side of Apple to Test.** If each apple is pressure tested once, test only the red or only the green side, because the red side frequently is harder than the green side (table 6). If each apple is pressure tested twice, opposite sides may be used and the first side selected at random. If each apple is tested 3 or 4 times, the first side is again selected at random.

plunges into the flesh and stops short of the scribed line, at the yield point noted in table 11. If the tip of the instrument is then forced to the scribed line, a higher value is obtained. The value recorded for firmness should be the force required to insert the instrument tip to the depth of the scribed line (7.9 mm, 5/16 inch).

**Recording to the Nearest Half Kilogram or Pound.** In a McIntosh experiment conducted in Maine, 20 apples per sample were pressure tested once (on the green side) at harvest and again after storage. The original pressure tester values were estimated to the nearest 0.2 pounds.

Table 10. Effect of plunger penetration speed on measured firmness of Delicious apples

Test	Slow (2.5 sec)	Normal (1.6 sec)	Fast (0.6 sec)
	kg (lb)	kg (lb)	kg (lb)
1	6.80 (15.0)	7.12 (15.7)	9.13 (20.1)
2	6.80 (15.0)	7.12 (15.7)	8.67 (19.1)
Average	6.80 (15.0)	7.12 (15.7)	8.90 (19.6)

Source: Claypool, L. L., R. B. Fridley, and Ross Johns. 1966. *Western Fruit Grower* 20(17):18-19.

Table 11. Effect of plunger penetration depth on measured firmness (New York tests)

Plunger penetration	McIntosh	Delicious	Spy
	kg (lb)	kg (lb)	kg (lb)
Yield point*	4.08a ( 9.0)	4.72a (10.4)	5.90a (13.0)
Scribed line†	4.31b ( 9.5)	4.90b (10.8)	6.31b (13.9)

\*When tip of plunger makes initial penetration.  
†7.9 mm (5/16 in.) from tip of plunger.

pound.

Table 12. Average firmness of McIntosh apples with individual pressure tester readings recorded to the nearest 0.2, 0.5, or 1.0 pound (Maine tests)

Strain	Harvest date	At harvest			After harvest		
		0.2	0.5	1.0	0.2	0.5	1.0
		pounds			pounds		
Rogers	September 11	16.1	16.1	16.1	10.8	10.8	10.8
	September 18	15.5	15.5	15.6	10.3	10.3	10.4
	September 26	12.7	12.7	12.6	9.0	9.0	9.1
G-29	September 11	15.7	15.7	15.7	11.0	11.0	11.1
	September 18	15.9	15.9	15.9	11.1	11.1	11.2
	September 26	13.2	13.2	13.2	8.1	8.1	8.0
Boller	September 11	15.8	15.9	15.8	10.9	10.9	10.8
	September 18	14.3	14.3	14.3	10.7	10.7	10.7
	September 26	13.3	13.3	13.3	10.0	10.0	10.0

These data were then reexamined to compare averages if the original data were recorded to the nearest 0.5 and 1.0 pound. The mean values, which appear in table 12, indicate that no greater precision would have been gained by recording to the nearest 0.5 or 0.2 pound than by recording to the nearest 1.0 pound. Therefore, recording each pressure tester reading to the nearest half kilogram or whole pound is adequate.

**Storage Breakdown and Decay.** Apples with abnormally soft flesh caused by decay or breakdown should not be included in the pressure test sample unless the pressure test is used as an index of breakdown. Data in table 13 illustrate the use of pressure test readings to index a soft-flesh breakdown of McIntosh apples. In this example the percentage of the apples below 3.2 kg (7 lb) was a better flesh breakdown index than were mean firmness values.

When breakdown, decay, or other factors that markedly influence pressure test readings are present, investigators should state in their report whether or not the affected apples were included in the pressure test sample.

Note: Twenty apples per sample tested once on green side. Original pressure tester value estimated to nearest 0.2 pounds. These data were reexamined to compare averages if original data were recorded to the nearest 0.5 and 1.0

Table 13. Poststorage firmness of McIntosh apples treated at harvest to reduce storage breakdown (New York tests)

Treatment below 3.2 kg (7 lb)	% of apples Mean firmness with apples below 3.2 kg (7 lb)	
	Included in sample	Excluded from sample
	kg (lb)	kg (lb)
1	42.5a 3.1a (6.8)	3.5a (7.6)
2	24.2b 3.3ab(7.2)	3.5ab(7.8)
3	10.0d 3.5b (7.6)	3.6ab(7.9)
4	18.4c 3.5b (7.7)	3.7b (8.2)

Note: Mean separation in columns by Duncan's multiple range test, 5% level.

## Summary

1. Table 1 can be used as a guide to the minimum sample size.
2. Use trees as replicates when possible.
3. Collect samples from trees of uniform vigor.
4. Pick the entire crop from trees or large limbs in randomized or standardized quadrants.
5. Avoid apples with watercore or be certain the extent of watercore development is the same within each replicate.
6. Select fruits with a maximum range in diameter of ¼ inch.
7. Test apples of similar temperature.
8. Check the instrument for calibration.
9. When using one pressure test per fruit, consistently test either the red or the green side.
10. Remove a uniformly thin skin disc (20-25 mm diam.) with a vegetable peeler or sharp knife.
11. Use one person for all tests or match operators with replicates.
12. Hold the fruit or the instrument against a hard, stationary surface.
13. Take 2 seconds to force the pressure tester tip to the depth of the scribed line.
14. Record readings to the nearest half kilogram or whole pound.
15. Discard apples affected by breakdown or decay.

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**Conversion Table — Pounds to Kilograms**

<i>Whole lb</i>	<i>Tenths of pounds</i>									
	<i>0</i>	<i>.1</i>	<i>.2</i>	<i>.3</i>	<i>.4</i>	<i>.5</i>	<i>.6</i>	<i>.7</i>	<i>.8</i>	<i>.9</i>
	<b>Kilograms</b>									
4	1.81	1.86	1.90	1.95	1.99	2.04	2.08	2.13	2.17	2.22
5	2.27	2.32	2.36	2.41	2.45	2.50	2.54	2.59	2.63	2.68
6	2.72	2.77	2.81	2.86	3.00	2.95	2.99	3.04	3.08	3.13
7	3.18	3.23	3.27	3.32	3.36	3.41	3.45	3.50	3.54	3.59
8	3.63	3.68	3.72	3.77	3.81	3.86	3.90	3.95	3.99	4.04
9	4.08	4.13	4.17	4.22	4.26	4.31	4.35	4.40	4.44	4.49
10	4.54	4.59	4.63	4.68	4.72	4.77	4.81	4.86	4.90	4.95
11	4.99	5.04	5.08	5.13	5.17	5.22	5.26	5.31	5.35	5.40
12	5.44	5.49	5.53	5.58	5.62	5.67	5.71	5.76	5.80	5.85
13	5.90	5.95	5.99	6.04	6.08	6.13	6.17	6.22	6.27	6.31
14	6.35	6.40	6.44	6.49	6.53	6.58	6.63	6.67	6.72	6.76
15	6.80	6.85	6.89	6.94	6.98	7.03	7.07	7.12	7.16	7.21
16	7.26	7.31	7.35	7.40	7.44	7.49	7.53	7.58	7.62	7.67
17	7.71	7.76	7.80	7.85	7.90	7.95	8.00	8.04	8.08	8.13
18	8.17	8.22	8.26	8.31	8.35	8.40	8.44	8.48	8.54	8.58
19	8.64	8.67	8.73	8.76	8.82	8.87	8.90	8.94	8.99	9.03
20	9.07	9.13	9.17	9.22	9.26	9.30	9.35	9.40	9.44	9.48
21	9.53	9.58	9.62	9.67	9.71	9.76	9.81	9.85	9.90	

9.94

$(2.21) \times (kg) = lb; (0.454) \times (lb) = kg$

Attention to the color of the tested side is important only when apples are tested once. Avoid making tests at bruised areas.

**Skin Removal.** If the skin is left intact, the pressure test measures the toughness of the skin as well as the firmness of the flesh (table 7). Therefore, the skin must be removed before pressure testing to obtain an accurate measure of flesh firmness.

**Depth of Cut.** If a deep cut is used to remove the skin before pressure testing, the firmness values will be significantly higher than if a shallow cut is used (table 8). Therefore, the operator should use a stainless steel vegetable peeler to remove the skin or use a sharp knife to remove discs about the size of a nickel or quarter (20-25 mm). The skin disc is removed from the cheek, midway between the stem and the calyx.

## Making the Test

**Individual Variation.** When 5 experienced operators each collected 25 apples from the top of a common bin and

pressure tested each fruit 4 times, the average firmness values they obtained were significantly different (table 9). It is best to use one trained person to do all the pressure testing for an experiment. If this is not possible or is undesirable, operators should be matched with replicates. Do not match operators with treatments.

**Speed of Punch.** In comparison with slow insertion, rapid insertion of the pressure tester tip results in higher firmness values (table 10). Each operator should develop the habit of taking about 2 seconds (for example count one-thousand-one, one-thousand-two) to insert the tip of the pressure tester to the scribed line. Uniform force on the instrument is essential to obtain repeatable results and is more easily obtained by using a pressure tester mounted on a drill press stand (see cover) than by using a hand-held instrument. If a hand-held instrument is used, the fruit or the instrument should be held against a hard, stationary surface such as a tree trunk, car body, bulk bin, or table. The pressure tester tip can then be forced into the flesh with uniform motion.

**Depth of Penetration.** After the skin disc has been removed, the instrument tip placed in contact with the flesh, and uniform force applied, the tip frequently

Table 6. Average firmness on the red and green sides of several apple varieties

Variety	State	Side of apple tested		Stat. sign.*
		Green	Red	
		kg (lb)	kg (lb)	
McIntosh	NY	8.44 (18.6)	9.03 (19.9)	†
McIntosh	PA	3.59 (7.9)	3.86 (8.5)	†
Cortland	NY	8.17 (18.0)	8.08 (17.8)	ns
Delicious	PA	5.62 (12.4)	5.71 (12.6)	ns
Delicious	VA	7.76 (17.1)	8.17 (18.0)	†
Stayman	PA	4.40 (9.7)	4.49 (9.9)	ns
Rome	NY	11.08 (24.4)	11.21 (24.7)	ns

\*†, *t* values significant at 5% level;  
ns, *t* values not significant at 5% level.

Table 8. Firmness of Idared apples pressure tested at various depths below the skin (New York tests)

Depth	Fruit diameter—cm (inches)		
	5.7-6.4 (2¼-2½)	7.0-7.6 (2¾-3)	8.3-8.9 (3¼-3½)
mm inches	kg (lb)	kg (lb)	kg (lb)
1 (.04)	5.17a (11.4)	4.72a (10.4)	4.59a (10.1)
5 (.20)	5.13a (11.3)	4.86b (10.7)	4.68a (10.3)
10 (.39)	5.90b (13.0)	5.49c (12.1)	5.58b (12.3)
15 (.59)	7.21c (15.9)	6.89d (15.2)	6.58c (14.5)

Note: Mean separation in columns by Duncan's multiple range test, 5% level.

Table 7. Effect of skin removal on measured firmness of apples

Variety	At harvest		After storage		
	Skin removed	Skin not removed	Skin removed	Skin not removed	
		kg (lb)	kg (lb)	kg (lb)	kg (lb)
McIntosh	6.13 (13.5)	8.40 (18.5)	3.68 (8.1)	5.80 (12.8)	
Delicious	7.16 (15.8)	8.31 (18.3)	4.49 (9.9)	7.58 (16.7)	
Rome	7.90 (17.4)	9.30 (20.5)	5.08 (11.2)	7.67 (16.9)	
Winesap	9.12 (20.1)	11.08 (24.4)	4.59 (10.1)	8.44 (18.6)	
Average	7.58 (16.7)	9.26 (20.4)	4.44 (9.8)	7.40 (16.3)	

Source: Magness, J. R. 1925. An improved type of pressure tester for the determination of fruit maturity. U.S.D.A. Cir. 350:7.

Table 9. Pressure test values obtained by 5 different testers sampling from the top of a bin of apples (New York tests)

Tester	R. I. Greening	Idared	Rome	Mean*
		kg (lb)	kg (lb)	kg (lb)
A	4.77 (10.5)	5.95 (13.1)	5.90 (13.0)	5.53a (12.2)
B	5.08 (11.2)	6.08 (13.4)	6.40 (14.1)	5.85b (12.9)
C	5.22 (11.5)	6.27 (13.8)	6.58 (14.5)	6.04bc (13.3)
D	5.71 (12.6)	6.31 (13.9)	6.49 (14.3)	6.17c (13.6)
E	6.04 (13.3)	6.67 (14.7)	6.98 (15.4)	6.58d (14.5)

\*Mean separation by Duncan's multiple range test, 5% level.