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## EFFECT OF FRUIT SIZE ON THE COOL STORAGE BEHAVIOUR OF GRANNY SMITH APPLES

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Martin (1953) has shown with a number of Tasmanian-grown apple varieties that the incidence of storage disorders in fruit from the same tree is positively correlated with fruit diameter. However, in commercial practice, it would be impracticable for growers to cool store different sized fruit from each tree separately. Invariably, fruit from each picking is mixed in the orchard, graded for size and packed into cases for subsequent storage and/or marketing. While it is generally recommended that fruit for long storage should not be extremely large or small, no information is available to indicate whether variations within the recommended size range for long storage have any major effect on the cool storage behaviour of apples. These investigations were therefore designed to determine whether size has any effect on the cool storage behaviour of the Granny Smith variety, grown in Queensland, picked at optimum storage maturity and stored at recommended temperatures. The investigations were carried out over the 3-year period 1962-1964.

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### Methods and Materials

Fruit for the experiments in each year was obtained from the same six orchards in the Granite Belt, surrounding Stanthorpe. In the 1962 experiment, 12 half-bushel cases were picked from each orchard, comprising three half-bushel cases of each of the following four sizes: 2½, 2¾, 3 and 3¼-in. diam. Fruit for the 1963 and 1964 experiments consisted of 18 half-bushel cases from each orchard, comprising three half-bushel cases of each of the following six sizes: 2½, 2¾, 3, 3¼, 3½ and 3¾-in. diam. Picking date in each season was April 17. This date falls within the period found by Stevenson and Watkins (1961) to be the most satisfactory for long storage of the Granny Smith variety, grown in Queensland. After picking, the fruit was wrapped in oiled paper wrappers to control superficial scald, railed to Brisbane and stored at the Food Preservation Research Laboratory, Hamilton, at 32°F. Removals from store were made as follows:

	1962	1963	1964
Removal 1 .. ..	Sept. 24	Sept. 25	Sept. 24
Removal 2 .. ..	Oct. 24	Oct. 23	Oct. 22
Removal 3 .. ..	Nov. 23	Nov. 20	Nov. 19

The fruit was then held for 7 days at 70°F and inspected for storage disorders. Firmness was measured on opposite sides of five fruit, selected at random from each case, with a Magness Penetrometer, using the  $\frac{7}{16}$ -in. plunger, and the mean of the 10 readings recorded. To determine the weighted core flush rating, the severity of the disorder in 5 fruit selected at random from each case was graded into absent, slight, medium and severe and a 0, 1, 2, 4 rating used. The rating for each sample of fruit was then deduced by expressing the recorded incidence as a percentage of the maximum amount of core flush possible.

### Results

*1962 experiment.*—The results of the 1962 experiment are summarized in Table 1. Because of the small amount of bitter pit, mould and withering present, analyses of variance were not carried out. Similarly, an analysis of variance was not carried out on superficial scald from removal 1. While there was more scald present in fruit from removals 2 and 3, size had no significant effect on the incidence of this disorder. There was too little breakdown in fruit from removals 1 and 2 to allow of an analysis of variance being carried out, but in fruit from removal 3 there was significantly more breakdown in the 3¼-in. diam. fruit than in the other, smaller fruit. Size had no significant effect on the total number of disorders present but significantly affected firmness, which decreased with increase in fruit size.

TABLE 1

1962 EXPERIMENT:—MEAN PERCENTAGES AND DEFECTS OF GRANNY SMITH APPLES AFTER REMOVAL FROM COOL STORE

Removal No.	Fruit Size (in)	Bitter Pit (%)	Superficial Scald (%)	Mould (%)	Breakdown (%)	Withering (%)	Total Disorders (%)	Firmness (lb)
1	2½	0.4	1.5	0.2	0	0.4	2.6	13.82
	2¾	0.8	1.3	0.6	0.6	0	3.3	13.56
	3	0.7	1.7	0	0.4	0	2.7	13.23
	3¼	1.5	1.7	1.5	2.8	0	7.4	12.67
2	2½	0	9.6	1.1	0.2	0.2	10.9	12.98
	2¾	0.3	12.6	1.4	0.6	0	14.8	12.57
	3	0	15.1	1.3	0	0	16.4	12.16
	3¼	0.5	16.2	6.0	1.0	0	22.7	11.58
3	2½	0	24.9	1.7	4.0	0	30.3	13.16
	2¾	0.6	30.1	1.3	3.1	0	33.4	12.84
	3	0	28.4	2.0	5.4	0	32.0	12.41
	3¼	0	21.9	2.0	17.8	0	41.3	12.00

Bitter Pit—No analysis of variance carried out.

Superficial Scald—Removal 1, no analysis of variance carried out.

Removal 2, no significant effect of size

Removal 3, no significant effect of size.

Mould—No analysis of variance carried out.

Breakdown—Removal 1, no analysis of variance carried out.

Removal 2, no analysis of variance carried out.

Removal 3, 2½ in., 2¾ in., 3 in. significantly less than 3¼ in. (5% level).

Withering—No analysis of variance carried out.

Total Disorders—Removals 1, 2 and 3, no significant effect of size.

Firmness—2½ in. significantly firmer than 3 in. and 3¼ in. (1% level).

2¾ in. significantly firmer than 3¼ in. (1% level).

2¾ in. significantly firmer than 3 in. (5% level).

3 in. significantly firmer than 3¼ in. (5% level).

Removal 1 significantly firmer than Removals 2 and 3 (1% level).

1963 experiment.—The results of the 1963 experiment are summarized in Table 2. With the exception of superficial scald, fruit size had a significant effect on the incidence of disorders during storage. The effect of size on bitter pit was confined to the very large fruit, namely 3½ and 3¾ in., which had significantly more bitter pit than the 2½-in. fruit. Mould incidence was significantly higher in larger fruit and was particularly severe in fruit above 3 in. diam. The incidence of breakdown was also significantly greater in the larger fruit, that above 3 in. diam. being seriously affected. The total number of disorders present, comprising bitter pit, scald, mould and breakdown, increased with increase in the size of the fruit. Firmness decreased significantly with increase in fruit size. Size had a significant effect on the severity of core flush, with the larger fruit being the most seriously affected.

TABLE 2

1963 EXPERIMENT:—MEAN PERCENTAGES AND DEFECTS OF GRANNY SMITH APPLES AFTER REMOVAL FROM COOL STORE

Removal No.	Fruit Size (in)	Bitter Pit (%)	Superficial Scald (%)	Mould (%)	Breakdown (%)	Total Disorders (%)	Firmness (lb)	Weighted Core Flush
1	2½	1.81	0.58	1.92	1.32	9.22	10.62	1.15
	2¾	4.97	0.44	0.57	2.37	11.62	10.57	3.17
	3	5.83	1.55	1.56	0.63	14.74	10.25	2.46
	3¼	6.08	1.77	0.74	2.52	16.36	9.68	4.76
	3½	5.77	0.56	2.13	3.42	18.61	9.55	7.88
	3¾	11.33	1.00	5.48	2.21	26.20	9.22	6.48
2	2½	3.21	2.63	1.31	2.98	16.43	11.05	11.27
	2¾	6.16	3.31	3.70	2.99	18.94	10.49	11.14
	3	9.55	4.07	4.21	2.62	24.01	10.42	8.66
	3¼	6.73	5.47	6.03	2.50	32.98	9.88	10.08
	3½	10.66	7.89	13.74	8.48	43.55	10.05	19.06
	3¾	10.32	10.84	11.38	12.93	41.75	9.44	27.30
3	2½	2.77	8.85	2.45	11.77	27.01	11.54	*
	2¾	0.95	13.45	8.12	12.77	31.43	11.57	*
	3	1.36	8.59	5.86	6.82	28.54	11.02	*
	3¼	4.76	11.22	11.54	19.86	41.56	10.63	*
	3½	3.74	8.30	23.29	21.42	49.89	10.76	*
	3¾	1.49	4.93	16.19	19.12	43.12	10.06	*

\* Not recorded

Bitter Pit—Removal 1 significantly greater than Removal 3 (1% level).

Removal 2 significantly greater than Removal 3 (1% level)

3½ in., 3¾ in. significantly greater than 2½ in. (5% level)

Superficial Scald—Removals 2 and 3 significantly greater than Removal 1 (1% level)

Removal 3 significantly greater than Removal 2 (5% level)

Size: no significant effect.

Mould—Removal 3 significantly greater than Removal 1 (1% level)

Removal 3 significantly greater than Removal 2 (5% level)

3½ in., 3¾ in. significantly greater than 2½ in., 2¾ in., 3 in. (1% level)

3½ in., 3¾ in. significantly greater than 3¼ in. (5% level)

3¼ in. significantly greater than 2½ in. (5% level)

Breakdown—Removal 3 significantly greater than Removals 1 and 2 (1% level)

Removal 2 significantly greater than Removal 1 (5% level)

3½ in., 3¾ in. significantly greater than 3 in. (1% level)

3½ in., 3¾ in. significantly greater than 2½ in., 2¾ in. (5% level)

3¼ in. significantly greater than 3 in. (5% level)

Total Disorders—

Removals 2 and 3 significantly greater than Removal 1 (1% level)

Removal 3 significantly greater than Removal 2 (1% level)

3¼ in., 3½ in., 3¾ in. significantly greater than 2½ in. (1% level)

3¼ in. significantly greater than 2¾ in., 3 in. (1% level)

3½ in., 3¾ in. significantly greater than 2¾ in., 3 in. (1% level)

Firmness—

Removal 3 significantly firmer than Removals 1 and 2 (1% level)

2½ in., 2¾ in. significantly firmer than 3¼ in., 3½ in., 3¾ in. (1% level)

3 in. significantly firmer than 3¾ in. (1% level)

## Weighted Core Flush—

Removal 2 significantly greater than Removal 1 (1% level)

3 $\frac{3}{4}$  in. significantly greater than 2 $\frac{1}{2}$  in., 3 in. (1% level)3 $\frac{3}{4}$  in. significantly greater than 2 $\frac{3}{4}$  in., 3 $\frac{1}{4}$  in. (5% level)3 $\frac{1}{2}$  in. significantly greater than 2 $\frac{1}{2}$  in., 3 in. (5% level)

As a general rule, the amount of disorders present increased significantly with increase in the length of the storage period. However, the incidence of bitter pit decreased with increase in the length of the storage period, though the decrease may in part be due to the difficulty of identifying this disorder when fruit is affected by mould or breakdown. Firmness increased with increase in the length of the storage period.

*1964 experiment.*—The results of the 1964 experiment are summarized in Table 3. In this year, fruit size had a significant effect on the incidence of all disorders present during storage. The effect of size on the incidence of bitter pit was confined to the very large fruit, namely that above 3 in. diam., which had significantly more pit than the 2 $\frac{1}{2}$ -in. fruit. Fruit greater than 3 in. diam. had significantly more superficial scald than the 2 $\frac{1}{2}$ -in. fruit. Mould and breakdown incidence was significantly higher in the larger fruit, as was also the total number of disorders present. Firmness decreased significantly with increase in fruit size. With the exception of bitter pit, the amount of disorders present increased significantly with increase in the length of the storage period.

TABLE 3

1964 EXPERIMENT:—MEAN PERCENTAGE AND DEFECTS OF GRANNY SMITH APPLES AFTER REMOVAL COOL STORE

Removal No.	Fruit Size (in)	Bitter Pit (%)	Superficial Scald (%)	Mould (%)	Breakdown (%)	Total Disorders (%)	Firmness (lb)
1	2 $\frac{1}{2}$	0.03	0.21	0.54	0.05	0.85	13.30
	2 $\frac{3}{4}$	0.01	0.09	0	0.01	0.25	12.96
	3	0.17	0.10	0.06	0.10	1.15	12.28
	3 $\frac{1}{4}$	0.63	0.18	0.16	0.01	1.91	12.04
	3 $\frac{1}{2}$	0.12	0.02	0.09	0.45	1.01	12.08
	3 $\frac{3}{4}$	0.54	0.22	0.82	0.63	3.07	11.63
2	2 $\frac{1}{2}$	0.07	0.17	0.84	0.02	0.77	12.68
	2 $\frac{3}{4}$	0.03	0.41	0.27	0.05	1.27	12.74
	3	0.10	0.24	0.79	0.09	1.12	12.46
	3 $\frac{1}{4}$	0.38	0.16	0.09	0.24	2.14	11.89
	3 $\frac{1}{2}$	0.30	0.16	1.16	0.69	2.94	11.51
	3 $\frac{3}{4}$	1.65	0.86	1.56	0.91	7.47	11.67
3	2 $\frac{1}{2}$	0.02	0.13	1.12	0.06	0.91	13.52
	2 $\frac{3}{4}$	0.57	0.50	1.09	0.35	2.46	12.68
	3	0.05	1.12	1.79	0.19	2.84	12.33
	3 $\frac{1}{4}$	0.18	2.52	0.38	0.43	7.29	12.13
	3 $\frac{1}{2}$	0.20	1.52	2.63	1.56	5.46	11.42
	3 $\frac{3}{4}$	0.27	2.75	6.68	3.91	12.56	11.38

- Bitter Pit— $3\frac{3}{4}$  in. significantly greater than  $2\frac{1}{2}$  in., 3 in. (1% level)  
 $3\frac{3}{4}$  in. significantly greater than  $2\frac{3}{4}$  in.,  $3\frac{1}{2}$  in. (5% level)  
 $3\frac{1}{4}$  in. significantly greater than  $2\frac{1}{2}$  in. (5% level)
- Superficial Scald—Removal 3 significantly greater than Removals 1 and 2 (1% level)  
 $3\frac{3}{4}$  in. significantly greater than  $2\frac{1}{2}$  in. (1% level)  
 $3\frac{3}{4}$  in. significantly greater than  $2\frac{3}{4}$  in., 3 in.,  $3\frac{1}{2}$  in. (5% level)  
 $3\frac{1}{4}$  in. significantly greater than  $2\frac{1}{2}$  in. (5% level)
- Mould—Removal 3 significantly greater than Removal 1 (1% level)  
Removal 3 significantly greater than Removal 2 (5% level)  
 $3\frac{3}{4}$  in. significantly greater than  $2\frac{3}{4}$  in.,  $3\frac{1}{4}$  in. (1% level)  
 $3\frac{3}{4}$  in. significantly greater than  $2\frac{1}{2}$  in., 3 in. (5% level)
- Breakdown—  
Removal 3 significantly greater than Removals 1 and 2 (1% level)  
 $3\frac{3}{4}$  in. significantly greater than  $2\frac{1}{2}$  in.,  $2\frac{3}{4}$  in., 3 in.,  $3\frac{1}{4}$  in. (1% level)  
 $3\frac{1}{2}$  in. significantly greater than  $2\frac{1}{2}$  in.,  $2\frac{3}{4}$  in., 3 in.,  $3\frac{1}{4}$  in. (1% level)
- Total Disorders—  
Removal 3 significantly greater than Removals 1 and 2 (1% level)  
 $3\frac{3}{4}$  in. significantly greater than  $2\frac{1}{2}$  in.,  $2\frac{3}{4}$  in., 3 in.,  $3\frac{1}{4}$  in. (1% level)  
 $3\frac{1}{2}$  in. significantly greater than  $2\frac{1}{2}$  in. (1% level)  
 $3\frac{1}{2}$  in. significantly greater than  $2\frac{3}{4}$  in. (5% level)  
 $3\frac{3}{4}$  in. significantly greater than  $2\frac{1}{2}$  in.,  $2\frac{3}{4}$  in. (1% level)  
 $3\frac{1}{4}$  in. significantly greater than 3 in. (5% level)
- Firmness—  
 $2\frac{1}{2}$  in. significantly firmer than 3 in.,  $3\frac{1}{4}$  in.,  $3\frac{1}{2}$  in.,  $3\frac{3}{4}$  in. (1% level)  
 $2\frac{3}{4}$  in. significantly firmer than  $3\frac{1}{4}$  in.,  $3\frac{1}{2}$  in.,  $3\frac{3}{4}$  in. (1% level)  
 $2\frac{3}{4}$  in. significantly firmer than 3 in. (5% level)  
3 in. significantly firmer than  $3\frac{1}{4}$  in.,  $3\frac{3}{4}$  in. (1% level)  
 $3\frac{1}{4}$  in. significantly firmer than  $3\frac{3}{4}$  in. (5% level)

### Discussion

Though there was variation in the incidence of storage disorders from season to season, in each year fruit above 3 in. in diameter was more severely affected by storage disorders than smaller fruit. There was also a progressive reduction in fruit firmness with increase in fruit size.

These results indicate that lengthy storage of the Granny Smith variety should be confined to fruit of 3 in. or less in diameter.

The pattern of incidence of superficial scald shows the variability and inadequacy of oiled paper wraps for the control of this disorder. However, until the use of chemical scald inhibitors is permitted, these wraps remain the best form of protection against superficial scald.

Increase in firmness of the fruit with increase in the length of the storage period, noted in the 1963 experiments, has been encountered in other investigations (Stevenson 1959). It cannot be satisfactorily explained, but it is thought that moisture losses from the fruit during storage, accompanied by some shrivelling, make the fruit more resistant to penetration by the test plunger.

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