INVESTIGATIONS INTO THE CONTROL OF SUPERFICIAL SCALD IN COOL-STORED QUEENSLAND GROWN GRANNY SMITH APPLES BY CHEMICAL MEANS

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SUMMARY:

Experiments were conducted over a 5-year period to determine whether superficial scald in Queensland grown and cool-stored Granny Smith apples could be controlled by chemical means.

Diphenylamine applied prior to storage either as a dip or incorporated in paper wraps effectively controlled scald over a wide range of maturities and under conditions of normal atmosphere and controlled atmosphere storage.

Scald control was effected even in atmospheres containing high concentrations of carbon dioxide, but when 10 per cent. carbon dioxide was present in the storage atmosphere, oiled paper wraps containing 15 per cent. mineral oil in addition to the diphenylamine treatment were necessary to obtain complete control.

Low concentrations of diphenylamine in addition to oiled paper wraps containing 15 per cent. mineral oil yielded control of the disorder equal to higher concentrations of the compound used alone.

Though control was effected irrespective of the maturity of the fruit at the time of picking, other storage disorders increased if very immature fruit was stored.

Diphenylamine appeared to have some control on the incidence of internal breakdown in the experimental fruit.

A number of other chemical compounds were tested for their scald-controlling properties and five were found to give a considerable measure of control.

I. INTRODUCTION

The most common disorder associated with the cool storage of the Granny Smith apple variety is a superficial browning of the skin called superficial scald. This disorder in Australian-grown apples has been described by Carne (1948) and in the Granny Smith variety was the subject of a histological study by Bain (1956), who found that only two or three layers of cells are affected. Its control in susceptible American varieties was investigated by Brooks, Cooley, and Fisher (1923), who discovered that wrapping the fruit in paper containing more than 15 per cent. of a high-grade mineral oil resulted in good control. This method was adopted commercially and is still used extensively with both Australian and overseas varieties of apples. Extensive additional investigations have been carried out throughout the world and the results have been reviewed by a number of workers, including Martin (1957) and Fidler (1959). Despite all the information obtained, the cause of the disorder remains unknown.

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Fidler (1956) investigated the effect of weather during the period of growth of the English-grown Edward VII variety over a 10-year period and found that from measurements of rainfall or sunshine it should be possible to predict whether scald would be absent or slight, moderate or severe. Tindale and Huelin (1939) and Padfield (1954) reported that delays between harvesting and storage considerably reduced the incidence of superficial scald in Granny Smith apples, but Stevenson (1957) showed that while scald incidence was reduced, delays caused increased susceptibility to other defects such as mould and soggy breakdown. Melville and Hardisty (1953) reported that scald in Granny Smith apples could be controlled by a reduction in storage temperature from 40°F after four weeks' storage to 32°F, but Padfield (1958) found that this method did not aid scald control on New Zealand Granny Smith apples stored for seven months.

Superficial scald has been found to be severe in early-picked fruit, and Tindale and Huelin (1939), Padfield (1950) and Stevenson (1957, 1959) have shown that later picking dates result in a considerable reduction of the disorder.

When controlled atmosphere storage methods are employed with the Granny Smith variety there is an increase in the amount of superficial scald with increase in the amount of carbon dioxide present in the storage atmosphere (Huelin and Tindale 1947; Stevenson 1957).

The most important discovery with respect to the control of this disorder was the treatment of apples, prior to storage, with dips containing diphenylamine (DPA) in low concentrations (Smock 1955). The effectiveness of diphenylamine as a means of controlling scald in the Granny Smith variety was soon demonstrated by Australian workers and by Padfield (1959) in New Zealand.

The work of Abood and Gerard (1953) on cytochrome oxidase suggested to Smock that control might be affected by diphenylamine, and the possible involvement of oxidative enzymes in scald incidence was later discussed by Smock (1957). Subsequent work by Patterson (1959) has shown that some enzyme systems seem to be involved, as he obtained control by hot-water blanching, and that anti-oxidants prevent scald after removal of the fruit from store.

In view of the promising results obtained by Smock with diphenylamine, investigations were commenced in Queensland in 1956 to determine the effect of this compound and a number of other anti-oxidants on superficial scald incidence on the Granny Smith variety grown on the Granite Belt, surrounding Stanthorpe, and held under refrigerated conditions in air and controlled atmosphere storage.

Most of the subsequent experiments were concerned with testing materials that might be more acceptable to public health authorities than DPA. Particular attention was given to other oxidase inhibitors. Efforts were also made to determine the lowest effective concentration of DPA. The effect of DPA on scald development in fruit picked over a wide range of maturity was given attention in several experiments.

Picking dates were varied from late February to late April; fruit picked later than the middle of April is not usually susceptible to superficial scald.

II. 1956 EXPERIMENT

Objective.—To assess the effect of diphenylamine on the control of superficial scald in fruit picked at two different stages of maturity and held in different storage atmospheres.

Fruit.—The experimental fruit was obtained from four orchards. The picking dates were April 9 and April 23.

Pre-storage Treatments.—Three treatments were used:

(1) Oiled paper wraps containing 15% mineral oil
(2) 1000 p.p.m. DPA in 35% ethyl alcohol dip
(3) Oiled paper wraps containing 15 per cent. mineral oil plus a 1000 p.p.m. DPA in 35% ethyl alcohol dip.

Storage and Post-storage.—The fruit was stored in eighteen 44 gal wide-mouthed, gastight drums, each drum containing fruit of one treatment from one picking date for three removals of each of 36 fruit from each of the four orchards.

The storage atmospheres were:

(1) 16% oxygen plus 5% carbon dioxide
(2) 11% oxygen plus 10% carbon dioxide
(3) 5% oxygen without carbon dioxide
(4) Normal air storage.

Regular analyses were made during the storage period with an Orsat gas analysis apparatus and any necessary alterations made with cylinders of nitrogen and carbon dioxide. In the case of the 5% oxygen atmosphere, the carbon dioxide given off by the enclosed fruit was removed by chemical reaction with 14 lb of commercial grade flake sodium hydroxide placed in a container at the bottom of each drum.

After packing and sealing, the drums were stored at the C.O.D. Cool Stores, Thulimbah, at approximately 34°F.

Removals from storage were made on October 2, November 13, and December 12, 1956.

Immediately after the fruit for the first and second removals had been taken from each drum, the drum was resealed, and the atmosphere corrected by gases from cylinders. After removal from store the fruit was held at air temperatures for seven days, to simulate normal marketing delays, and was then inspected for storage disorders.

Results.—The results are summarized in Tables 1-7.

Table 1 shows that very little superficial scald was present when DPA dips were used and up to 5% carbon dioxide was present in the storage atmosphere. A concentration of 10 per cent. carbon dioxide in the storage atmosphere resulted in a greater amount of scald present even when DPA dips were

TABLE 1

SUPERFICIAL SCALD IN DPA TREATMENTS. 1956 EXPERIMENT

(Equivalent Mean Percentages)

Treatment*	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1	R2	R3	M3	M4	Mean
1000p.p.m.DPA ..	1·0	2·0	1·6	10·0	·1	3·0	7·8	7·1	·1	3·6
1000p.p.m.DPA+Wraps	·2	0	·1	1·4	0	·3	1·0	·8	0	·4
M3 (Picked Apr. 9) ..	1·0	2·0	1·6	11·3	·1	3·3	8·6			4·0
M4 (Picked Apr. 23) ..	·2	0	·1	0	0	0	·2			·1
R1 (Removed Oct. 1) ..	0	0	·2	0						0
R2 (Removed Nov. 13)	·3	·4	1·4	4·5						1·6
R3 (Removed Dec. 12) ..	1·5	2·6	1·0	12·5						4·4
Mean	·6	1·0	·9	5·7	0	1·6	4·4	4·0	·1	2·0

No analysis of variance was carried out because of the small amount of the disorder present.

TABLE 2

SUPERFICIAL SCALD WITH OILED PAPER WRAPS ONLY. 1956 EXPERIMENT

(Equivalent Mean Percentages)

Storage Treatment	R1*	R2	R3	M3	M4	Mean
Air Storage	0	6·4	1·0	4·7	·1	1·5
5%O_2	2·5	19·5	9·1	24·1	1·0	9·2
16%O_2 5%CO_2	22·5	69·1	74·5	90·6	16·6	55·4
11%O_2 10%CO_2	32·3	81·9	92·5	81·1	61·2	71·7
M3	26·4	63·3	58·9			49·2
M4	1·0	22·4	22·6			12·6
Mean	9·8	42·1	40·0	49·2	12·6	29·1

* R1, R2, R3, M3 and M4 as in Table 1.

R1 significantly less than R2 and R3 (1% level).

M4 significantly less than M3 (1% level) for all four atmospheres and the three removals.

Interaction of Atmospheres x Removals highly significant

For R1, Air Storage and 5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide and 11% oxygen plus 10% carbon dioxide (1% level).

For R2, Air Storage and 5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide and 11% oxygen plus 10% carbon dioxide (1% level).

For R3, Air Storage significantly less than 5% oxygen (5% level); 5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide (1% level); 16% oxygen plus 5% carbon dioxide significantly less than 11% oxygen plus 10% carbon dioxide (1% level). Loss of reactive power of NaOH in drums considered to be cause of higher scald in 5% oxygen than in normal atmosphere.

used. However, the use of oiled paper wrappers containing 15% mineral oil in addition to a DPA dip reduced the scald incidence to almost zero when the fruit was stored in this high carbon dioxide atmosphere. Because of the small amount of scald present in the experimental fruit treated with DPA, the effect of time of picking and length of the storage period on the storage behaviour of fruit treated with this compound could not be analysed statistically.

When oiled paper wraps alone were used (Table 2), considerable scald was present. Fruit from the first removal had less scald than that from either of the two later removals, and fruit from the second pick was less affected than fruit from the first pick.

The effect of storage atmosphere on scald incidence with oiled paper wraps was related to the length of the storage period and the carbon dioxide concentration (see footnote to Table 2). Both the increase in the incidence of the disorder with longer storage periods and the increase with high carbon dioxide concentrations in the storage atmosphere were highly significant.

There was a highly significant increase in mould with increase in the length of the storage period (Table 3). In addition, fruit from the first pick had significantly less mould than that from the second pick.

TABLE 3

MOULD IN 1956 EXPERIMENT

(Equivalent Mean Percentages)

Treatment*	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1	R2	R3	M3	M4	Mean
Wraps	7·3	2·1	1·0	1·5	1·1	2·5	4·7	1·6	3·8	2·6
1000p.p.m.DPA ..	9·9	2·8	4·2	4·9	1·8	5·2	10·3	3·3	7·4	5·2
1000p.p.m.DPA+Wraps	4·8	2·3	2·1	2·6	1·2	2·2	6·3	1·6	4·5	2·9
M3	4·5	1·7	1·4	1·5	1·0	1·6	4·3			2·1
M4	10·5	3·3	3·4	4·7	1·7	5·2	10·2			5·1
R1	2·0	·8	·9	1·8						1·3
R2	3·4	3·3	2·4	3·7						3·2
R3	22·0	3·7	4·0	3·2						6·9
Mean	7·2	2·4	2·3	2·8	1·3	3·2	6·9	2·1	5·1	3·5

* R1, R2, R3, M3 and M4 as in Table 1.

R1 significantly less than R2 (1% level).

R2 significantly less than R3 (1% level).

M3 significantly less than M4 (1% level).

Oiled paper wraps, 1000 p.p.m. DPA plus oiled paper wraps significantly less than 1000 p.p.m. DPA (1% level).

Interaction of Atmospheres x Removals highly significant.

For R1, no difference between atmospheres.

For R2, no difference between atmospheres.

For R3, 5% oxygen ; 16% oxygen plus 5% carbon dioxide ; 11% oxygen plus 10% carbon dioxide significantly less than Air Storage (1% level).

Very little soggy breakdown was encountered in the experiment irrespective of whether the fruit was wrapped, unwrapped or treated with DPA (Table 4). However, in fruit stored under normal atmospheres there was a definite increase of the disorder with increase in the length of the storage period and, in addition, fruit from the first pick had more soggy breakdown than fruit from the second pick. Because of the small amount of the disorder present an analysis of variance was not carried out.

TABLE 4

SOGGY BREAKDOWN IN 1956 EXPERIMENT

(Equivalent Mean Percentages)

Treatment*	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1	R2	R3	M3	M4	Mean
Wraps	9·5	1·6	·5	1·2	·2	1·5	7·9	3·6	2·7	3·2
1000p.p.m.DPA ..	3·9	·6	·5	2·6	·1	1·6	3·9	2·3	1·5	1·9
1000p.p.m.DPA+Wraps	6·1	2·8	·1	2·3	·2	1·9	6·3	2·2	3·5	2·8
M3	8·6	1·2	·4	·6	·1	1·2	6·7			2·7
M4	4·4	2·2	·3	3·4	·3	2·1	5·3			2·6
R1	·6	·1	0	·1						·2
R2	3·9	1·0	·1	1·5						1·6
R3	15·0	3·8	·9	4·4						6·0
Mean	6·5	1·7	·3	2·0	·2	1·6	6·0	2·7	2·6	2·6

* R1, R2, R3, M3 and M4 as in Table 1.

No analysis of variance was carried out because of the small amount of the disorder present.

Analyses of total wastage, which included wastage from mould, soggy breakdown and superficial scald, showed that there was a significant increase in wastage with increase in the length of the storage period, and that the effect of storage atmosphere was highly significant (Tables 5 and 6).

The firmness of the fruit was significantly affected by the length of the storage period (Table 7), inasmuch as fruit from the first removal was firmer than that from the second and third removals. Fruit from the first pick was not as firm as that from the second pick. Air-stored fruit was not as firm as fruit stored in an atmosphere of 5% oxygen, which in turn was not as firm as that stored in the 16% oxygen plus 5% carbon dioxide or the 11% oxygen plus 10% carbon dioxide atmospheres.

There is some evidence from the results that DPA dips had an effect on the firmness of the fruit. Under an atmosphere of 5% oxygen, fruit in oiled paper wraps was significantly softer than that treated with DPA irrespective of whether the treated fruit was wrapped or not. There were also some effects on firmness due to DPA dips when fruit was stored under atmospheres of either 5% oxygen or 16% oxygen plus 5% carbon dioxide.

TABLE 5

TOTAL BREAKDOWN WITH OILED PAPER WRAPS ONLY. 1956 EXPERIMENT

(Equivalent Mean Percentages)

Storage Treatment	R1*	R2	R3	M3	M4	Mean
Air Storage	2·3	15·4	56·5	24·7	16·5	20·4
$5\%O_2$	4·4	29·2	20·7	30·7	6·1	16·5
$16\%O_2$ / $5\%CO_2$	25·4	74·0	80·7	93·0	21·6	60·7
$11\%C_2$ / $10\%CO_2$	39·9	85·6	97·0	85·6	70·3	78·4
M3	30·1	70·1	81·1			61·2
M4	4·3	32·2	51·1			26·1
Means	14·7	51·2	67·0	61·2	26·1	43·2

* R1, R2, R3, M3 and M4 as in Table 1.

M4 significantly less than M3 (1% level).

Interactions of Atmospheres x Removals and Atmospheres x Maturities are highly significant.

For R1 and R2, Air Storage and 5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide and 11% oxygen plus 10% carbon dioxide (1% level).

For R3, 5% oxygen significantly less than Air Storage (1% level) ; Air Storage significantly less than 16% oxygen plus 5% carbon dioxide (1% level) ; 16% oxygen plus 5% carbon dioxide significantly less than 11% oxygen plus 10% carbon dioxide (1% level).

For Air Storage, no difference in maturities.

For 5% oxygen and 16% oxygen plus 5% carbon dioxide ; M4 significantly less than M3 (1% level) ; R1 significantly less than R2 and R3 (1% level).

For 11% oxygen and 10% carbon dioxide, M4 significantly less than M3 (5% level) ; R1 significantly less than R2 (1% level) ; R2 significantly less than R3 (5% level).

TABLE 6

TOTAL BREAKDOWN IN DPA TREATMENTS. 1956 EXPERIMENT
(Equivalent Mean Percentages)

Treatment*	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1	R2	R3	M3	M4	Mean
1,000 p.p.m. DPA	14·1	5·1	7·2	16·1	2·4	9·7	23·0	11·9	8·5	10·1
1,000 p.p.m. DPA + Wraps ..	10·6	4·3	3·0	6·0	1·3	4·7	14·4	4·5	6·9	5·7
M3	11·0	4·5	5·0	12·2	1·9	6·5	19·2			7·8
M4	13·7	4·8	4·7	9·0	1·7	7·5	17·7			7·7
R1	2·7	1·0	2·2	1·4						1·8
R2	7·0	3·9	5·5	12·7						7·0
R3	35·5	12·0	7·5	23·4						18·5
Mean	12·3	4·7	4·8	10·5	1·8	7·0	18·5	7·8	7·7	7·7

* R1, R2, R3, M3 and M4 as in Table 1.

DPA dips + oiled paper wraps significantly less than DPA dips (1% level).

R1 significantly less than R2 (1% level).

R2 significantly less than R3 (1% level).

5% oxygen and 16% oxygen plus 5% carbon dioxide significantly less than 11% oxygen plus 10% carbon dioxide and Air Storage (1% level).

Interactions of Treatments x Maturities and Atmospheres x Removals are significant.

For M3, DPA dips + oiled paper wraps significantly less than DPA dips (1% level).

For M4, no difference in Treatments.

For R1, no difference in Atmospheres.

For R2, 5% oxygen significantly less than 11% oxygen plus 10% carbon dioxide (1% level) ; 16% oxygen plus 5% carbon dioxide significantly less than 11% oxygen plus 10% carbon dioxide (1% level).

For R3, 16% oxygen plus 5% carbon dioxide and 5% oxygen significantly less than 11% oxygen plus 10% carbon dioxide (1% level) ; 11% oxygen plus 10% carbon dioxide significantly less than Air Storage (5% level).

TABLE 7

FIRMNESS (LB) OF FRUIT IN 1956 EXPERIMENT

Treatment	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1*	R2	R3	M3	M4	Mean
Wraps	11·06	12·25	13·33	13·81	11·88	13·20	12·77	12·48	12·75	12·61
1,000 p.p.m. DPA	10·75	12·81	13·58	13·48	12·06	12·89	13·02	12·47	12·84	12·66
1,000 p.p.m. DPA + Wraps	10·96	12·81	13·67	13·23	12·03	12·95	13·02	12·54	12·79	12·67
M3	10·72	12·46	13·42	13·39	11·91	12·76	12·82			12·50
M4	11·12	12·79	13·64	13·62	12·07	13·27	13·04			12·80
R1	10·54	12·10	12·67	12·65						11·99
R2	11·31	12·88	13·94	13·94						13·02
R3	10·92	12·90	13·98	13·94						12·93
Mean	10·92	12·62	13·53	13·51	11·99	13·02	12·93	12·50	12·80	12·65

* R1, R2, R3, M3 and M4 as in Table 1.

R1 significantly less than R2 and R3 (1% level).

M3 significantly less than M4 (1% level).

Air Storage significantly less than 5% Oxygen (1% level).

5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide and 11% oxygen plus 10% carbon dioxide (1% level).

For Removals and Maturities, no difference between treatments.

Interaction of Treatments × Atmospheres is significant.

For Air Storage and 16% oxygen plus 5% carbon dioxide, no difference between treatments.

For 5% oxygen, Oiled paper wraps significantly less than DPA dips and DPA dips plus oiled paper wraps (5% level).

For 11% oxygen plus 10% carbon dioxide, DPA dips plus oiled paper wraps significantly less than oiled paper wraps (5% level).

III. 1957 EXPERIMENT

Objective.—To assess the effect of various anti-oxidants, both cytochrome and polyphenol oxidase inhibitors, on the incidence of superficial scald.

TABLE 8

SUPERFICIAL SCALD. 1957 EXPERIMENT

Treatment	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean (%)
1. Untreated control (sulphite paper wraps)	94·0	96·0	98·0	96·0
2. Oiled paper wraps (15 % mineral oil)	8·0	0	58·0	22·0
3. 1·8 mg DPA impregnated paper wraps (1·8 mg DPA/10 in. square)	4·0	0	0	1·3
4. 3·6 mg DPA impregnated paper wraps (3·6 mg DPA/10 in. square)	0	0	0	0
5. 1,000 p.p.m. DPA dip plus oiled paper wraps (15% mineral oil)	0	0	4·0	1·3
6. 500 p.p.m. DPA dip plus oiled paper wraps (15% mineral oil)	4·0	0	0	1·3
7. 1,000 p.p.m. DPA dip	0	0	2·0	0·7
8. 5,000 p.p.m. DPA dip	2·0	0	0	0·7
9. 2,000 p.p.m. diphenyloxide dip	86·0	76·0	84·0	82·0
10. 500 p.p.m. diphenyloxide dip	98·0	90·0	96·0	94·7
11. 2,000 p.p.m. thiourea dip	98·0	90·0	82·0	90·0
12. 500 p.p.m. thiourea dip	74·0	94·0	88·0	85·3
13. 2,000 p.p.m. salicylic acid dip	90·0	94·0	94·0	92·7
14. 500 p.p.m. salicylic acid dip	10·0	100·0	78·0	62·7
15. 2,000 p.p.m. p hydroxydiphenyl dip	30·0	66·0	66·0	54·0
16. 500 p.p.m. p hydroxydiphenyl dip	86·0	88·0	100·0	91·3
17. 2,000 p.p.m. sodium azide dip	6·0	98·0	92·0	65·3
18. 500 p.p.m. sodium azide dip	56·0	94·0	66·0	72·0
19. 2,000 p.p.m. sodium diethyldithiocarbamate dip	64·0	92·0	96·0	84·0
20. 500 p.p.m. sodium diethyldithiocarbamate dip	90·0	92·0	100·0	94·0
21. 2,000 p.p.m. diaminoethanetetraacetic acid—disodium salt dip	100·0	96·0	98·0	98·0
22. 500 p.p.m. diaminoethanetetraacetic acid—disodium salt dip	92·0	88·0	96·0	92·0
23. 2,000 p.p.m. L cysteine hydrochloride dip	90·0	96·0	100·0	95·3
24. 500 p.p.m. L cysteine hydrochloride dip	84·0	90·0	96·0	90·0
25. 2,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	2·0	0	0	0·7
26. 500 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	0	0	0
27. 2,000 p.p.m. diphenylthiocarbazone dip	30·0*	50·0*	92·0*	57·3
28. 500 p.p.m. diphenylthiocarbazone dip	72·0	36·0*	84·0	64·0
29. 2,000 p.p.m. 2 thiouracil dip	96·0	100·0	64·0	86·7
30. 500 p.p.m. 2 thiouracil dip	96·0	72·0	40·0	69·3
31. 2,000 p.p.m. phenylthiourea dip	88·0	96·0	94·0	92·7
32. 500 p.p.m. phenylthiourea dip	80·0	82·0	66·0	76·0
33. 2,000 p.p.m. cobalt sulphate dip	94·0	88·0	98·0	93·3
34. 500 p.p.m. cobalt sulphate dip	46·0	64·0	62·0	57·3
35. 500 p.p.m. diphenylbenzidene dip	90·0	100·0	90·0	93·3
36. 95% ethyl alcohol dip	98·0	92·0	86·0	92·0

* Injury to fruit present.

Fruit.—Fruit for the experiment was obtained from one orchard and was 2½ in. in diameter. The fruit was picked in March to ensure that it would be susceptible to superficial scald during the storage period.

Pre-storage Treatments.—Thirty-six different treatments were used in the experiment. They are given in Table 8. Wherever possible, aqueous solution dips were used, but with non-water-soluble substances ethyl alcohol was used as the solvent. Each treatment consisted of 150 fruit. After dipping the fruit was drained and allowed to dry.

Storage and Post-storage.—The 150 dipped fruit in each treatment were divided into three replicates each containing 50 fruit, and replicates for six treatments were packed into each of eighteen 44 gal drums in a randomized manner to obviate drum effects. After packing, the drums were sealed and stored in the Hamilton Cool Stores, Brisbane, at 34°F. The atmospheres within the drums were maintained at 16% oxygen plus 5% carbon dioxide to encourage development of superficial scald. The drums were sealed on April 16, and removed from the storage chamber and opened on November 11, 1957. The fruit was held at atmospheric temperatures for seven days, to simulate normal marketing delays, and then inspected for the incidence of superficial scald.

Results.—Of the 36 treatments used in the experiment, only nine had any marked effect on the incidence of the disorder (Table 8). Six were diphenylamine applied either as a dip or incorporated in paper wraps, and two involved the use of 6 ethoxy 12 dihydro 224 trimethylquinoline in dip form. Oiled paper wraps, while not so effective as diphenylamine or 6 ethoxy 12 dihydro 224 trimethylquinoline, yielded good results.

Some of the remaining compounds used in the experiment gave good control in one of the replicates but not in the other two. An inspection of the arrangement of the treatments in the experimental containers revealed that where this occurred the replicate was adjacent to either a diphenylamine or a 6 ethoxy 12 dihydro 224 trimethylquinoline treatment and a proximity effect was thus involved.

IV. 1958 EXPERIMENTS

(a) Experiment 1

Objective.—To assess the effect of a number of compounds, including some structurally similar to DPA, on superficial scald.

Fruit.—Fruit was obtained from one orchard and was of 2½ in. diameter. It was picked in late March to ensure susceptibility to superficial scald during the storage period.

Pre-storage Treatments.—The 36 treatments used are listed in Table 9. They were applied as ethyl alcohol solutions. Each treatment consisted of 150 fruit. After treatment the fruit was drained and allowed to dry.

Storage and Post-storage.—The dipped fruit was divided into three replicates of 50 fruit and replicates for six treatments were packed into each of eighteen

44 gal drums. To obviate drum effects, the replicates were randomized in the drums. After packing, the drums were sealed and stored in the Hamilton Cool Stores, Brisbane, at 34°F. The atmospheres inside the drums were maintained at 16% oxygen plus 5% carbon dioxide to encourage the development of scald. Removal of the drums from the storage chamber was made on October 29, 1958. The drums were then opened and the fruit held at atmospheric temperatures for seven days. An inspection was then made and the amount of superficial scald recorded.

TABLE 9
SUPERFICIAL SCALD. EXPERIMENT 1, 1958

Treatment	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean (%)
1. Oiled paper wraps (15% mineral oil)	48·0	32·0	56·0	45·3
2. Untreated control (sulphite paper wraps)	86·0	52·0	96·0	78·0
3. DPA impregnated paper wraps (3·6 mg/10 in. square)	2·0	2·0	0	1·3
4. DPA impregnated paper wraps (1·8 mg/10 in. square)	6·0	0	0	2·0
5. 1,000 p.p.m. DPA dip plus oiled paper wraps (15% mineral oil)	0	0	0	0
6. 500 p.p.m. DPA dip plus oiled paper wraps (15% mineral oil)	0	0	2·0	0·7
7. 1,000 p.p.m. DPA dip	2·0	0	0	0·7
8. 500 p.p.m. DPA dip	14·0	8·0	8·0	10·0
9. 2,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	0	0	0
10. 1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	2·0	8·0	3·3
11. 2,000 p.p.m. phenothiazine dip	86·0	60·0	72·0	72·7
12. 1,000 p.p.m. phenothiazine dip	76·0	90·0	88·0	84·7
13. 2,000 p.p.m. adenine dip	100·0	88·0	100·0	96·0
14. 1,000 p.p.m. adenine dip	42·0	98·0	88·0	76·0
15. 2,000 p.p.m. pyrrole dip	96·0	96·0	92·0	94·7
16. 1,000 p.p.m. pyrrole dip	94·0	92·0	86·0	90·7
17. 2,000 p.p.m. piperidine dip	48·0	90·0	92·0	76·7
18. 1,000 p.p.m. piperidine dip	96·0	92·0	88·0	92·0
19. 2,000 p.p.m. pyrrolidine dip	34·0	92·0	90·0	72·0
20. 1,000 p.p.m. pyrrolidine dip	90·0	92·0	88·0	90·0
21. 2,000 p.p.m. carbamilide dip	92·0	100·0	98·0	96·7
22. 1,000 p.p.m. carbamilide dip	90·0	98·0	100·0	96·0
23. 2,000 p.p.m. carbazole dip	90·0	80·0	92·0	87·3
24. 1,000 p.p.m. carbazole dip	98·0	88·0	96·0	94·0
25. 2,000 p.p.m. p phenylenediamine dip	94·0	78·0	96·0	89·3
26. 1,000 p.p.m. p phenylenediamine dip	98·0	78·0	94·0	90·0
27. 2,000 p.p.m. diphenylguanidine dip	92·0	96·0	98·0	95·3
28. 1,000 p.p.m. diphenylguanidine dip	98·0	92·0	96·0	95·3
29. 2,000 p.p.m. 24 dinitrophenylhydrazine dip	94·0	100·0	92·0	95·3
30. 1,000 p.p.m. 24 dinitrophenylhydrazine dip	94·0	96·0	70·0	86·7
31. 2,000 p.p.m. methyl p aminophenol dip	82·0	90·0	80·0	84·0
32. 1,000 p.p.m. methyl p aminophenol dip	86·0	98·0	94·0	92·7
33. 2,000 p.p.m. hexamine dip	90·0	100·0	98·0	96·0
34. 1,000 p.p.m. hexamine dip	100·0	92·0	92·0	94·7
35. 2,000 p.p.m. phenacetin dip	96·0	100·0	94·0	96·7
36. 1,000 p.p.m. phenacetin dip	56·0	96·0	92·0	81·3

Results.—The results are summarized in Table 9. Only nine treatments had any marked effect on the incidence of superficial scald. Six involved the use of diphenylamine either as a dip or incorporated in paper wraps, two were dips of 6 ethoxy 12 dihydro 224 trimethylquinoline and one was the standard oiled paper wraps. None of the other materials were of any use in controlling scald despite their similarity in structure to diphenylamine. As in the 1957 experiment, some apparent control was observed in one or more of the replicates of the ineffective treatments. This effect was once more shown to be due to experimental fruit being adjacent to either a diphenylamine or a 6 ethoxy 12 dihydro 224 trimethylquinoline replicate.

(b) Experiment 2

Objective.—To determine the amount of control of superficial scald effected by diphenylamine dips over a more extended picking period than that used in earlier experiments.

Fruit.—The fruit was obtained from six orchards and the picking dates were March 20, March 27, April 3, April 10, April 17, and April 24.

Pre-storage treatments.—The following pre-storage treatments were used in the investigations:—

(1) Untreated control.

(2) 1000 p.p.m. diphenylamine dip.

(3) Untreated fruit in 0·015 gauge polyethylene case liners.

(4) 1000 p.p.m. diphenylamine dip with fruit in 0·015 gauge polyethylene case liners.

One half-bushel case was taken from each orchard at each picking date for each treatment, making a total of 144 half-bushel cases. Polyethylene case liners were used to create modified controlled atmospheres with carbon dioxide contents in excess of that normally found in the atmosphere so that the effect of high concentrations of this gas could be studied over a range of picking dates.

Storage and Post-storage.—After treatment, the fruit was cool-stored in the Hamilton Cool Stores, Brisbane, at 34°F within 48 hr of harvest date. Removals from store were made seven months later. After removal from store the fruit was held for seven days at atmospheric temperatures and then inspected for superficial scald incidence.

Results.—The results are summarized in Table 10. No scald was present in DPA-treated fruit irrespective of the time of picking and the atmosphere

under which the fruit was stored. There was no decrease in scald incidence, in the untreated controls, with increase in maturity. In the untreated fruit there was no evidence that polyethylene liners increased scald incidence.

TABLE 10

SUPERFICIAL SCALD. EXPERIMENT 2, 1958

Picking Date	Treatment			
	A (%)	B (%)	C (%)	D (%)
March 20	97·7	0	98·5	0
March 27	98·7	0	99·4	0
April 3	92·7	0	96·5	0
April 10	95·4	0	97·0	0
April 17	86·7	0	96·1	0
April, 24	93·8	0	96·6	0

V. 1959 EXPERIMENTS

(a) Experiment 1

Objective.—To assess the effect of a number of treatments on superficial scald.

Fruit.—The fruit was obtained from one orchard and was of 2½ in. diameter. It was picked late in March to ensure susceptibility to superficial scald during the storage period.

Pre-storage treatments.—The treatments used are shown in Table 11. They were applied as alcoholic solutions or, where solution could not be effected, fine suspensions in ethenol. Each treatment consisted of 150 fruit.

Storage and Post-storage.—The treated fruit was divided into three replicates of 50 fruit and replicates for six treatments were packed into one of eighteen 44 gal drums. To obviate drum effects the replicates were randomized in the drums. After packing, the drums were sealed and stored in the Hamilton Cool Stores, Brisbane, at 34°F. The atmospheres within the drums maintained at 16% oxygen plus 5% carbon dioxide. Removal of the drums from the storage chamber was made on October 26, 1959. The drums were then opened and the fruit held under normal atmospheric conditions for seven days. An inspection was then made and the amount of superficial scald recorded.

Results.—The results are summarized in Table 11. Of the 36 treatments, 12 gave marked control of superficial scald. Four of these involved diphenylamine or 6 ethoxy 12 dihydro 224 trimethylquinoline. Other treatments

which gave good control were NN′ diphenyl p phenylenediamine, p hydroxydiphenylamine, and diphenylcarbamylchoride. N phenyl 1 napthylamine gave good control at 1000 p.p.m. concentrations but at the higher concentration (5000 p.p.m.) was not so effective. Both 1, 2, 3, 4 tetrahydroisoquinoline and p amino diphenylamine appeared to give slight control at the concentrations used and are worthy of further investigations.

TABLE 11

SUPERFICIAL SCALD. EXPERIMENT 1, 1959

Treatment	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean (%)
1. Untreated control—sulphite paper wraps	100·0	100·0	100·0	100·0
2. Oiled paper wraps (15% mineral oil)	96·0	90·0	100·0	95·3
3. 1,000 p.p.m. diphenylamine dip	0	0	0	0
4. 5,000 p.p.m. diphenylamine dip	0	0	0	0
5. 1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	0	0	0
6. 5,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	6·0	10·0	5·3
7. 1,000 p.p.m. p aminobenzoic acid dip	100·0	100·0	100·0	100·0
8. 5,000 p.p.m. p aminobenzoic acid dip	92·0	100·0	94·0	95·3
9. 1,000 p.p.m. p phenylenediamine dip	100·0	100·0	100·0	100·0
10. 5,000 p.p.m. p phenylenediamine dip	100·0	100·0	100·0	100·0
11. 1,000 p.p.m. acridone dip*	100·0	100·0	100·0	100·0
12. 5,000 p.p.m. acridone dip*	100·0	100·0	100·0	100·0
13. 1,000 p.p.m. 1,234 tetrahydroisoquinoline dip	80·0	80·0	96·0	85·3
14. 5,000 p.p.m. 1,234 tetrahydroisoquinoline dip	96·0	100·0	96·0	97·3
15. 1,000 p.p.m. theophylline dip	100·0	100·0	100·0	100·0
16. 5,000 p.p.m. theophylline dip	100·0	100·0	100·0	100·0
17. 1,000 p.p.m. NN′ diphenyl p phenylenediamine dip*	0	12·0	10·0	7·3
18. 5,000 p.p.m. NN′ diphenyl p phenylenediamine dip*	6·0	4·0	6·0	5·3
19. 1,000 p.p.m. N phenyl 1 naphthylamine dip	0	14·0	0	4·7
20. 5,000 p.p.m. N phenyl 1 naphthylamine dip	52·0	52·0	100·0	68·0
21. 1,000 p.p.m. p hydroxydiphenylamine dip	0	0	0	0
22. 5,000 p.p.m. p hydroxydiphenylamine dip	0	0	0	0
23. 1,000 p.p.m. p amino diphenylamine dip†	70·0	84·0	90·0	74·7
24. 5,000 p.p.m. p amino diphenylamine dip†	100·0	94·0	100·0	98·0
25. 1,000 p.p.m. acridine dip	100·0	100·0	100·0	100·0
26. 5,000 p.p.m. acridine dip	100·0	100·0	100·0	100·0
27. 1,000 p.p.m. piperazine dip	100·0	100·0	100·0	100·0
28. 5,000 p.p.m. piperazine dip	100·0	100·0	100·0	100·0
29. 1,000 p.p.m. sym diethyldiphenylurea dip	100·0	92·0	100·0	97·3
30. 5,000 p.p.m. sym diethyldiphenylurea dip	100·0	100·0	100·0	100·0
31. 1,000 p.p.m. diphenylcarbamylchloride dip	0	0	0	0
32. 5,000 p.p.m. diphenylcarbamylchloride dip	0	0	10·0	3·3
33. 1,000 p.p.m. diphenylsuccinate dip	100·0	100·0	100·0	100·0
34. 5,000 p.p.m. diphenylsuccinate dip	100·0	100·0	100·0	100·0
35. 1,000 p.p.m. N (naphthyl) ethylenediamine dip	100·0	100·0	100·0	100·0
36. 5,000 p.p.m. N (naphthyl) ethylenediamine dip	98·0	100·0	100·0	99·3

* Residue on fruit.

† Skin damage to fruit.

(b) Experiment 2

Objective.—To assess the effect of diphenylamine on scald incidence over a range of early picking dates.

Fruit.—Fruit was obtained from four orchards. The picking dates were February 23, March 9, March 23, and April 6, 1959.

Pre-storage Treatment.—Three treatments were used in the investigation:—

(1) Control—oiled paper wraps containing 15% mineral oil and stored under normal atmospheric cool storage conditions.

(2) Diphenylamine wraps containing 1·8 mg DPA/10 in. square and stored under normal atmospheric cool storage conditions.

(3) Diphenylamine wraps containing 1·8 mg DPA/10 in. square and stored under controlled atmospheres of 16% oxygen plus 5% carbon dioxide.

Four half-bushel cases of fruit were harvested from each orchard at each of the four picking dates for each of the three treatments. Removals of the experimental fruit from store were made at the end of September and the end of October, 1959. After removal, the fruit was held for seven days at atmospheric temperatures and then inspected for superficial scald incidence.

Results.—The results are summarized in Tables 12 and 13.

TABLE 12

SUPERFICIAL SCALD. EXPERIMENT 2, 1959

Treatment	First Removal*				Second Removal			
	M1 (%)	M2 (%)	M3 (%)	M4 (%)	M1 (%)	M2 (%)	M3 (%)	M4 (%)
Oiled paper wraps—air storage	72·9	74·9	46·3	15·2	63·3	69·3	47·9	15·9
DPA wraps 1·5 mg/10 in. square—air storage ..	2·6	2·2	2·5	0·4	2·9	3·8	7·5	1·9
DPA wraps 1·5 mg/10 in. square—16% O_2 plus 5% CO_2	13·5	14·1	6·4	1·3	7·0	9·5	2·1	0·9

* Picking dates—M1, Feb. 23 ; M2, Mar.9 ; M3, Mar. 23 ; M4, Apr. 6.

TABLE 13

INTERNAL BREAKDOWN. EXPERIMENT 2, 1959

Treatment	Second Removal*			
	M1 (%)	M2 (%)	M3 (%)	M4 (%)
Oiled pape· wraps—air storage	90·0	82·5	78·7	82·5
DPA wraps 1·5 mg/10 in. square—air storage ..	80·0	66·3	77·5	51·3
DPA wraps 1·5 mg/10 in. square—16% O_2 plus 5% CO_2	56·3	20·0	38·8	6·3

* Picking dates as in Table 12.

The diphenylamine-treated wraps considerably reduced the incidence of superficial scald in fruit stored under normal atmospheres and in a controlled atmosphere of 16% oxygen plus 5% carbon dioxide. The increase in maturity of fruit stored in oiled paper wraps resulted in a decrease in the amount of the disorder present. There is a trend which suggests that fruit treated with diphenylamine wraps and held under an atmosphere containing a high carbon dioxide concentration was more susceptible to the disorder than fruit held under normal atmospheres, particularly in the early maturities.

Ten fruit from each case of the second removal were cut and the amount of internal breakdown recorded. Table 13 summarizes the results. Internal breakdown was very prevalent in both the control and the air-stored fruit treated with diphenylamine wraps. When the fruit was stored in an atmosphere of 16% oxygen plus 5% carbon dioxide the incidence of this disorder was considerably reduced. In addition, there appears to be a trend to a reduction in breakdown with increase in maturity in the fruit stored under the controlled atmosphere. Diphenylamine appears to have caused a reduction in internal breakdown in the fruit stored at normal atmospheres. A similar reduction has been reported by Padfield (1959).

(c) Experiment 3

Objective.—To assess the effect on superficial scald of very low concentrations of diphenylamine used alone and in conjunction with oiled paper wraps.

Fruit.—The fruit was obtained from three orchards and was picked on April 1, 1959.

TABLE 14

SUPERFICIAL SCALD. EXPERIMENT 3. 1959

Treatment	Superficial Scald (%)
Control (sulphite paper wraps)	92·5
Oiled paper wraps (15% mineral oil)	3·8
50 p.p.m. diphenylamine dip	46·9
100 p.p.m. diphenylamine dip	74·7
200 p.p.m. diphenylamine dip	24·2
400 p.p.m. diphenylamine dip	16·3
800 p.p.m. diphenylamine dip	2·5
50 p.p.m. diphenylamine dip plus oiled paper wraps ..	3·0
100 p.p.m. diphenylamine dip plus oiled paper wraps ..	4·8
200 p.p.m. diphenylamine dip plus oiled paper wraps ..	0
400 p.p.m. diphenylamine dip plus oiled paper wraps ..	0
800 p.p.m. diphenylamine dip plus oiled paper wraps ..	0

Pre-storage Treatments.—The treatments used are shown in Table 14.

Storage and Post-storage.—After treatment, the fruit was stored in the Hamilton Cool Stores, Brisbane at 34°F. Removal from the storage chamber was made on November 2, 1959, and after holding for seven days at atmospheric temperatures the fruit was inspected for superficial scald incidence.

Results.—Table 14 summarizes the results. Scald incidence was very high in the control lots but was very well controlled by oiled paper wraps containing 15% mineral oil. There was a gradual decrease in the incidence of the disorder with increase in the diphenylamine content of the dips used. A dip of 800 p.p.m. gave slightly better control than the oiled paper wraps. When a diphenylamine dip was used in conjunction with oiled paper wraps, complete control of scald was effected where the diphenylamine content of the dip was 200 p.p.m. or greater.

VI. 1960 EXPERIMENTS

(a) Experiment 1

Objective.—To retest compounds that had given some control of superficial scald in previous experiments.

Fruit.—Fruit was obtained from one orchard and was of 2½ in. diameter. It was harvested during the first week of April to ensure susceptibility to superficial scald.

Pre-storage treatments.—The 16 treatments used are shown in Table 15. Each treatment was applied as an alcoholic solution and consisted of 75 fruit divided into three replicates each of 25. Replicates for 16 treatments were one of three 44 gal drums, and to obviate drum effects the replicates were randomized in the drums.

TABLE 15

SUPERFICIAL SCALD. EXPERIMENT 1, 1960

Treatment	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean (%)
1. 5,000 p.p.m. diphenylamine dip	0	0	0	0
2. 1,000 p.p.m. diphenylamine dip	0	0	0	0
3. 5,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	0	0	0
4. 1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	10·0	0	0	3·3
5. 5,000 p.p.m. p. hydroxydiphenylamine dip	0	0	0	0
6. 1,000 p.p.m. p hydroxydiphenylamine dip	36·9	35·0	45·0	39·0
7. 5,000 p.p.m. diphenylcarbamylchloride dip	0	0	0	0
8. 1,000 p.p.m. diphenylcarbamylchloride dip	25·0	25·0	20·0	23·3
9. 5,000 p.p.m. N phenyl 1 naphthylamine dip	15·0	0	0	5·0
10. 1,000 p.p.m. N phenyl 1 naphthylamine dip	80·0	50·0	45·0	58·3
11. 5,000 p.p.m. sym dimethyldiphenylurea dip	100·0	100·0	100·0	100·0
12. 1,000 p.p.m. sym dimethyldiphenylurea dip	100·0	95·0	100·0	98·3
13. 5,000 p.p.m. NN′ diphenyl p phenylenediamine dip	5·0	0	0	1·7
14. 1,000 p.p.m. NN′ diphenyl p phenylenediamine dip	20·0	25·0	35·0	26·7
15. 5,000 p.p.m. nordihydroguairetic acid dip	100·0	100·0	90·0	96·7
16. 1,000 p.p.m. nordihydroguairetic acid dip	100·0	100·0	100·0	100·0

Storage and Post-storage.—After packing, the drums were sealed and stored in the Hamilton Cool Stores, Brisbane, at 34°F. The atmospheres within the drums were maintained at 16% oxygen plus 5% carbon dioxide. The drums

were removed from the storage chamber on October 27, 1960, opened, and held at atmospheric temperatures for seven days. An inspection of the fruit was then carried out and the incidence of superficial scald recorded.

Results.—The results are summarized in Table 15. Of the 16 treatments used, only four failed to effect any control of superficial scald. The 12 successful treatments were those that yielded good control in the 1959 experiment. Both diphenylamine and 6 ethoxy 12 dihydro 224 trimethylquinoline gave good control irrespective of concentrations, but p hydroxydiphenylamine, diphenylcarbamyl-chloride, N phenyl 1 napthylamine and NN′ diphenyl p phenylenediamine were more effective at the 5000 p.p.m. level.

(b) Experiment 2

Objective.—To compare 6 ethoxy 12 dihydro 224 trimethylquinoline with diphenylamine and oiled paper wraps for superficial scald control.

Fruit.—The fruit was obtained from one orchard and was picked during the first week in April.

Pre-storage treatments.—The treatments used in the experiment were—

(1) Oiled paper wraps containing 15% mineral oil.
(2) 1000 p.p.m. diphenylamine dip.
(3) 500 p.p.m. diphenylamine dip.
(4) 1000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip.
(5) 500 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip.

Four replicates of each treatment were used.

Storage and Post-storage.—After packing, the fruit was stored in the Hamilton Cool Stores, Brisbane, at 34°F. It was removed from the storage chamber on October 27, 1960, held for seven days at atmospheric temperatures and then inspected for superficial scald.

Results.—The results are summarized in Table 16. No scald was present in any fruit treated with either diphenylamine or 6 ethoxy 12 dihydro 224 trimethylquinoline, while the fruit wrapped in oiled paper wraps was moderately affected by the disorder.

TABLE 16

SUPERFICIAL SCALD. EXPERIMENT 2, 1960

Treatment	Superficial Scald (%)
1. Oiled paper wraps	13·7
2. 1,000 p.p.m. diphenylamine dip	0
3. 500 p.p.m. diphenylamine dip	0
4. 1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0
5. 500 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0

(c) Experiment 3

Objective.—To determine at what stage after picking diphenylamine and 6 ethoxy 12 dihydro 224 trimethylquinoline should be used for superficial scald control.

Fruit.—Eleven half-bushel cases of fruit were obtained from one orchard. The fruit was picked during the first week in April to ensure scald susceptibility.

Pre-storage Treatment.—After picking, the fruit was packed into cases and two cases were treated prior to storage with 1000 p.p.m. diphenylamine and 1000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dips respectively.

Storage and Post-storage.—All cases were stored in the Hamilton Cool Stores, Brisbane. Two of the naked cases were removed from store at intervals of 6 weeks, treated with the test compounds and then returned to the storage chamber. One case remained untreated throughout the storage period. The fruit was removed from the storage chamber on October 27, 1960, held for seven days at atmospheric temperatures and then inspected for scald incidence.

Results.—The results are summarized in Table 17. There was a gradual increase in the incidence of superficial scald with delay in application of either diphenylamine or 6 ethoxy 12 dihydro 224 trimethylquinoline.

TABLE 17

SUPERFICIAL SCALD. EXPERIMENT 3, 1960

Time of Application (weeks after storage)	1,000 p.p.m. diphenylamine dip (%)	1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip (%)
0	0	1·4
6	5·6	1·4
12	20·5	30·0
18	36·1	58·3
24	56·4	77·8
Untreated Control	63·3	

VII. DISCUSSION

From the results obtained in the experiments, it is clear that the development of superficial scald in stored Granny Smith apples may be controlled by treatment prior to storage with DPA either as a pre-storage dip or incorporated in paper wraps.

The concentration of DPA required depends on the storage atmosphere and the maturity of the fruit at picking.

Dipping in DPA 1000 p.p.m. is better than wrapping in oiled paper wraps and gives almost complete control of superficial scald in air storage and in

controlled atmospheres containing up to 5% carbon dioxide. At 10% carbon dioxide level, oiled paper wraps were necessary in addition to the DPA dip. For air storage, dips containing less than 800 p.p.m. DPA are not as effective as oiled paper wraps in controlling superficial scald, but a dip of 200 p.p.m. DPA, together with oiled paper wraps, gives complete control.

Wraps impregnated with DPA give a good measure of control of superficial scald. The concentrations used were 1·8 mg DPA per 10 in. square and 3·6 mg DPA per 10 in. square. There is an indication that with very susceptible (i.e. early harvested) fruit, a higher concentration than 1·8 mg per 10 in. square is necessary for complete control. This conforms with the results of E. G. Hall (private communication 1959), who showed that the concentration of DPA required to effect complete control should be varied with the susceptibility of the fruit to the disorder.

Though effective control of superficial scald on very susceptible fruit may be obtained by the use of DPA of appropriate strength, DPA treatment does not reduce the incidence of some other serious storage disorders in early-picked fruit. However, DPA does appear to effect some reduction in the incidence of internal breakdown.

Of the compounds tested because of their similarity in properties or structure to DPA, five have given effective control of superficial scald in various experiments. These are 6 ethoxy 12 dihydro 224 trimethylaquinoline, p hydroxydiphenylamine, diphenylcarbamychloride, N phenyl 1 napththylamine, and NN′ diphenyl p phenylenediamine. In view of the doubtful position with regard to the toxicity of DPA to human beings in the form of residues on fruit, these compounds are worthy of further study. It is interesting to note that 6 ethoxy 12 dihydro 224 trimethylquinoline has been cleared by the United States Food and Drug Administration for commercial use on apples.

Throughout the series of experiments, little information as to the cause of superficial scald or the manner of action of the effective inhibitors of scald development was obtained.

However, it appears significant that diphenylamine 6 ethoxy 12 dihydro 224 trimethylquinoline and NN′ diphenyl p phenylenediamine have been used as anti-oxidants for B-carotene in stock feeds and that phenothiazine, claimed to have scald-controlling properties on some overseas apple varieties, also has been used for the same purpose. It therefore appears that an investigation into the role of B-carotene in scald incidence may be of value in determining the cause of this disorder. Another avenue worthy of consideration is the examination of bisphenol derivatives as controllers of superficial scald, as their value as antioxidants for carotene has been demonstrated by Bickoff, Livingston, and Thompson (1955).

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