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MAINTENANCE OF CITRUS SEED VIABILITY

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SUMMARY

A number of factors which might affect the germination of stored citrus seed were investigated. These included varieties, extraction methods, storage period, storage temperature, fungicidal treatments and germination techniques.

Seed viability can be maintained in storage for long periods provided the seed retains its initial moisture content, is kept cool and is protected with a suitable fungicide. Seed should be washed after extraction from the fruit, superficially dried, treated with Spergon and stored at temperature within the 5-10°C range in sealed polyethylene bags.

Seed of Emperor and Cleopatra mandarins retain their viability better than those of rough lemon and Joppa sweet orange, particularly when the storage period exceeds 6 months.

Laboratory germination data for seed with the seed-coat unopened give a better correlation with germination in the seedbed than laboratory data from seed in which the seed-coat is opened before test.

Most storage and seed extraction methods which maintain the viability of the seed also result in quick germination. However, some fungicidal treatments retard germination.

I. INTRODUCTION

Seed of citrus rootstocks is supplied to nurserymen in Queensland through the Citrus Budwood and Seed Distribution Scheme, which is operated by the State Department of Primary Industries in conjunction with the Queensland Nurserymen's Association and the Committee of Direction of Fruit Marketing, a fruit and vegetable growers' co-operative organization. The main varieties handled are rough lemon, Joppa sweet orange and Emperor mandarin.

About 250 lb of seed are extracted and distributed to nurseries each year. In some seasons, germination in both the laboratory and the seedbed has been unsatisfactory. These investigations were designed to isolate the causal factors.

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Normally, the seed is extracted by hand, washed, dried in the shade, dusted with "Spergon" and packed for distribution to nurseries in brown-paper bags. Viability of the seed is assessed in the laboratory by first snipping off a portion of the seed coat with scissors and then germinating replicate samples at a constant temperature of 25°C for 28 days. The practice of opening the seed coat was originally introduced to shorten the germination period in the laboratory. A minimum of 50% germination is prescribed for citrus seed by State regulations.

The period of seed viability in storage varies considerably. Richards (1952) recorded a loss in germination within 7 days. Barton (1943) held seed without loss of viability for more than 12 months. Most authors stress the need to prevent the seed from drying out and for storage at about 5°C (see Childs and Hrnciar 1948; Fu 1951; Chapot 1955; Bacchi 1958; Montenegro and Salibe 1960; Nauer and Roistacher 1962). A wide range of fungicidal seed dressings has been tested by Childs and Hrnciar (1948), Ryan (1958), Nauer and Roistacher (1962) and Said (1963). Barton (1943), Richards (1952) and Montenegro and Salibe (1960) all found that species and varieties differ in their storage behaviour.

The investigations reported here were carried out between 1950 and 1961. Factors studied included the citrus variety, extraction method, fungicidal dressing, seed treatment prior to germination, storage period and storage temperature. The value of laboratory seed germination data as an indication of seedbed performance was also checked.

II. METHODS

In all trials, the seed was stored in sealed packages and laboratory germinations were made at a constant temperature of 25°C. The inverse sine transformation was used in analysing germination percentage for all trials. However, actual rather than the transformed percentages are recorded in the tables.

(a) Trial 1: Effects of Fungicidal Treatment and Storage Conditions

Design.—3 x 5 duplicated factorial.

Treatments.—

Storage Period and Temperature	Fungicidal Treatment
1. Nil storage	1. Copper carbonate
2. 28 days' storage at approx. 5°C	2. Thiram
3. 28 days' storage at room temperature (20°C)	3. " Spergon "
	4. " Agrosan "
	5. Nil

Methods.—Joppa seed was extracted, washed and dried in the shade. Samples weighing 2 oz. were dusted with the nominated fungicide, stored according to the schedule and then germinated in the laboratory. Seed-coats were opened prior to germination tests.

Results.—The laboratory germination data (Table 1) show that viability deteriorated in seed stored at room temperature (20°C) but not at 5°C. Spergon proved the best seed dressing and was particularly effective in seed held at room temperature.

TABLE 1

TRIAL 1: EFFECTS OF FUNGICIDAL TREATMENT AND STORAGE CONDITIONS ON GERMINATION PERCENTAGE

Joppa sweet orange

Fungicidal Treatment	Storage Period and Temperature			Mean
	(1) Nil Storage	(2) Cold Storage (5°C) for 28 Days	(3) Storage for 28 Days at Room Temp. (20°C)	
(1) Copper carbonate	71	77	64	71
(2) Thiram	80	71	57	67
(3) "Spergon"	84	88	81	84
(4) "Agrosan"	84	76	59	73
(5) Untreated	68	80	61	70
Mean	77	78	64	73

Significant differences—

Between fungicidal treatments (5% level): $3 > 1,2,5$

Between storage treatments (1% level): $1,2 \gg 3$

(b) Trial 2: Effects of Storage Conditions and Pregermination Treatment

Design.—4 x 6 x 3 duplicated factorial with split plots for pregermination treatments.

Treatments.—

Variety	Storage Period	Storage Temperature	Pregermination Treatment
Rough lemon	Nil	5°C	Seed-coat unopened
Joppa sweet orange ..	2 weeks	25°C	Seed-coat opened
Emperor mandarin ..	1 month		
Cleopatra mandarin ..	3 months		
	6 months		
	9 months		

Methods.—The seed was oven-dried at 40°C for 2 hr and dusted with Spergon. Samples each of 100 seeds were packaged in sealed polyethylene bags (0·0015 in.). Just prior to germination test in the laboratory, each sample was divided into two subsamples of 50 seeds which were subjected to the pregermination treatments.

Results.—The laboratory germination data (Table 2) indicate that interactions between treatments involve a time factor. Seed which was surface-dried and packaged in polyethylene steadily lost its viability in storage but the deterioration was not commercially significant until the storage period exceeded 6 months.

TABLE 2

TRIAL 2: EFFECTS OF STORAGE CONDITIONS AND PREGERMINATION TREATMENT ON GERMINATION PERCENTAGE

Rough lemon, Joppa sweet orange, Emperor and Cleopatra mandarins

Storage Period	Variety*				Pregermination Treatment		Storage Temperature		Means
	(1) Rough Lemon	(2) Joppa	(3) Emperor	(4) Cleo-patra	(1) Un-opened Seed	(2) Seed-coat Opened	(1) 5°C	(2) 25°C	
(1) Nil	99·1	98·1	99·6	99·9	98·8	99·7	99·3	99·4	99·3
(2) 2 weeks	95·6	89·5	98·6	97·3	92·5	98·2	95·6	95·9	95·8
(3) 1 month	97·4	93·8	99·4	98·0	93·3	99·7	98·3	96·6	97·5
(4) 3 months ..	92·1	82·7	94·7	87·2	84·0	94·2	93·8	84·6	89·6
(5) 6 months ..	93·2	85·3	93·6	96·2	88·8	95·5	95·6	88·6	92·5
(6) 9 months ..	29·9	54·6	68·8	81·4	43·0	74·5	86·9	27·8	59·2
Means	89·2	86·2	95·1	95·0	86·5	95·8	95·7	86·8	91·8

Significant differences—

Between storage periods (1% level): 2⩾4,6: 4,5⩾6: 1⩾2,4,5,6: 3⩾4,5,6. Differences greatest with (a) rough lemon and Joppa orange, (b) intact seed, (c) storage at 25°C.

Between variety means (1% level): 3,4⩾1,2

Between pregermination treatment means (1% level): 2⩾1

Between storage temperature means (1% level): 1⩾2

*Moisture content of seed before storage (% of fresh weight): rough lemon 36·0, Joppa orange 46·8, Emperor mandarin 48·0, Cleopatra mandarin 39·8.

Emperor and Cleopatra mandarin seed maintained their viability better than rough lemon and Joppa sweet orange. This effect was most apparent in seed stored for 9 months. However, the Joppa seed had a lower initial germination and viability deteriorated more or less steadily throughout the experimental period.

Seed stored at 5°C maintained its viability fairly well throughout the storage period. When stored at 25°C, viability decreased with time but not significantly so within 6 months.

Opened seed germinated better than unopened seed. The differences in percentage germination between treatments increased with the length of the storage period and were very pronounced after 6 months. By that time, the germination of the opened seed was more than 70% higher than that of the unopened seed.

The mean germination period (Table 3) was least in rough lemon, followed by Emperor mandarin, Cleopatra mandarin and Joppa sweet orange in that order.

TABLE 3

TRIAL 2: EFFECTS OF STORAGE CONDITIONS AND PREGERMINATION TREATMENT ON MEAN GERMINATION PERIOD (DAYS)*

Rough lemon, Joppa sweet orange, Emperor and Cleopatra mandarins

Variety	Pregermination Treatment		Means
	(1) Unopened Seed	(2) Seed-coat Opened	
(1) Rough lemon	10·0	8·1	9·1
(2) Joppa	16·7	11·2	13·9
(3) Emperor	12·9	9·7	11·3
(4) Cleopatra	14·4	10·4	12·4
Means	13·5	9·9	11·7

Significant differences—

Between varieties (1% level): $2 \geqslant 4 \geqslant 3 \geqslant 1$

Between pregermination treatments (1% level): $1 \geqslant 2$. Differences between unopened and opened seed vary with the variety.

* $\dfrac{\text{(No. germinating daily X No. days from sowing)}}{\text{Total No. germinated}}$

Seed with the seed-coat opened germinated more quickly than unopened seed; the magnitude of this difference was influenced by the variety, being greatest with Joppa sweet orange and least with rough lemon.

In general, the longer the seed was kept at a temperature of 25°C, the longer the mean germination period (Table 4). With seed kept at 5°C, the mean germination period remained more or less constant irrespective of the storage period. An exception to the above trends occurred in seed stored for 2 weeks.

TABLE 4

TRIAL 2: EFFECTS OF PERIOD AT 5 AND 25°C ON MEAN GERMINATION PERIOD (DAYS)

Mean of four varieties

Storage Period	Storage Temperature		Means
	(1) 5°C	(2) 25°C	
(1) Nil	10·6	11·0	10·8
(2) 2 weeks	12·8	11·9	12·3
(3) 1 month	11·2	11·1	11·1
(4) 3 months	10·8	13·1	12·0
(5) 6 months	10·4	14·0	12·2

Significant differences—

Between storage period means (1% level): 4,5≫1; 2≫1,3. Germination period increases with long storage but only where seed is stored at 25°C.

Between storage temperature means (1% level): 2≫1

(c) Trial 3: Effects of Packaging Material, Storage Temperature and Pregermination Treatment

Design.—6 x 4 duplicated factorial with split plots for pregermination treatments.

Treatments.—

Packaging Material	Storage Temperature	Pregermination Treatment
Muslin	1. 5°C	Seed-coat unopened
Brown paper	2. 10°C	Seed-coat opened
Polyethylene (·0015 in.)	3. 15°C	
Polyethylene (·004 in.)	4. 25°C	
Polyvinylchloride (·004 in.)		
" Cellophane "		

Methods.—Joppa sweet orange seed was oven-dried at 40°C for 2 hr and dusted with Spergon. Samples each of 100 seeds were packaged in sealed envelopes fabricated from the nominated materials, and stored at the prescribed temperatures for 3 months. Just prior to germination tests in the laboratory, each sample was divided into two subsamples of 50 seeds and subjected to pregermination treatments.

Results.—Very low germination percentages were recorded in some treatments and this precluded a complete analysis of the data. However, the following trends were apparent (Table 5):—

(1) The germination percentage in unopened seed was much lower than that of opened seed. This difference was very pronounced with seed stored in muslin, brown paper, polyvinylchloride and Cellophane.

(2) Germination percentages declined with storage temperature above 10°C.

(3) Unopened seed stored in muslin, brown paper, polyvinylchloride and Cellophane germinated poorly.

(4) The viability of seed stored in muslin, brown paper or Cellophane and opened prior to test fell from an average of 74% at a temperature of 15°C to nil at a temperature of 25°C.

TABLE 5

TRIAL 3: EFFECTS OF PACKAGING MATERIAL, STORAGE CONDITIONS AND PREGERMINATION TREATMENT ON GERMINATION PERCENTAGE

Joppa sweet orange

Packaging Material	Storage Temperature				Pregermination Treatment		Means
	5°C	10°C	15°C	25°C	Unopened Seed	Seed-coat Opened	
Muslin	30·0	27·5	43·5	0	2·8	47·7	25·3
Brown paper	40·0	43·0	39·0	0	4·2	56·8	30·5
Polyethylene ·0015 in.	76·5	72·5	41·5	46·0	37·2	81·0	59·1
Polyethylene ·004 in.	77·0	76·0	58·5	55·5	44·2	89·2	66·7
Polyvinylchloride ·004 in.	53·5	47·5	27·0	43·0	11·5	74·2	42·8
"Cellophane"	46·5	38·5	32·5	0	2·0	56·5	29·3
Means	53·9	50·8	40·3	24·1	17·0	67·6	42·3

* Moisture content: 44·1% fresh weight; germination at extraction: 93·5% (unopened) 97·5% (opened).

(5) Opened seed stored in polyethylene germinated more quickly than unopened seed (Table 6), the period of germination being least at 10°C, followed by 5, 25 and 15° in that order. The results were not affected by the thickness of the polyethylene film.

TABLE 6

TRIAL 3: EFFECTS OF STORAGE TEMPERATURE AND PREGERMINATION TREATMENT ON MEAN GERMINATION PERIOD (DAYS)

Joppa sweet orange in polyethylene

Pregermination Treatment	Storage Temperature				Means
	(1) 5°C	(2) 10°C	(3) 15°C	(4) 25°C	
(1) Unopened seed	14·7	13·6	16·2	15·7	15·0
(2) Seed-coat opened	10·4	9·3	11·1	10·8	10·4
Means	12·5	11·4	13·7	13·3	12·7

Significant differences—

Between pregermination treatments (1% level): $1 \geqslant 2$

Between storage temperatures:

5% level .. .. 3>1,2; 4>2

1% level .. .. $3,4 \geqslant 2$

(6) Storage temperatures ranging from 5 to 15°C had no effect on the viability of opened seed kept in different packaging materials. However, the mean germination period (Table 7) was less in seed stored in brown paper, muslin and ·004-in. polyethylene than in seed stored in polyvynilchloride, ·0015-in. polyethylene and Cellophane in that order.

TABLE 7

TRIAL 3: EFFECTS OF PACKAGING MATERIAL ON MEAN GERMINATION PERIOD (DAYS)

Joppa sweet orange. Stored at 5, 10 and 15°C and opened prior to germination

Treatments	Germination Period
(1) Muslin	9·7
(2) Brown paper	9·5
(3) Polyethylene ·0015 in.	10·7
(4) Polyethylene ·004 in.	9·8
(5) Polyvinylchloride ·004 in.	10·5
(6) " Cellophane "	11·1
Mean	10·2

Significant differences—

5% level .. .. 5>2; 3>1,2; 6>1,2,4

1% level .. .. 6≫1,2

(d) Trial 4: Effects of Prestorage Treatments, Storage Conditions and Pregermination Treatment

Design.—2 x 4 x 2 x 2 duplicated factorial with split plots for pregermination treatments.

Treatments.—

Washing	Drying	Storage Temperature	Storage Period	Pregermination Treatment
Juice and pulp not removed	Not dried	5°C	Nil	Seed-coat unopened
Juice and pulp removed by washing	Oven-dried for 2 hr at 40°C	25°C	3 months	Seed-coat opened
	Oven-dried for 24 hr at 40°C			
	Oven-dried for 48 hr at 40°C			

Methods.—Cleopatra mandarin seed was extracted, treated according to the schedule and dusted with Spergon. Samples each of 100 seeds were packaged in sealed polyethylene (·0015-in.) envelopes. Samples from half of the treatments were germinated in the laboratory immediately and the balance after a period of 3 months. The moisture content of duplicate samples from the various washing and drying treatments was determined.

Results.—The washing treatments had no effect on the moisture content of seed prior to storage. Drying treatments reduced the moisture content progressively with time (Table 8).

TABLE 8

TRIAL 4: EFFECTS OF DRYING AND WASHING TREATMENTS ON MOISTURE CONTENT OF SEED PRIOR TO STORAGE

Cleopatra mandarin. Moisture content as percentage of fresh weight

Drying Treatment	Washing Treatment	
	Not Washed	Washed
Nil	47·6	46·1
Oven-dried, 2 hr (40°C)	37·7	38·2
Oven-dried, 24 hr (40°C)	7·5	5·4
Oven-dried, 48 hr (40°C)	3·7	4·9

Germination percentages were very low in seed subjected to 24-hr and 48-hr drying treatments and the data were excluded from the analyses (Tables 9 and 10). Seed in all treatments deteriorated in storage. This was very marked with seed (a) stored at 25°C; (b) dried before storage; and (c) germinated with the seed-coat unopened.

TABLE 9

TRIAL 4: EFFECTS OF PRESTORAGE TREATMENTS, STORAGE CONDITIONS AND PREGERMINATION TREATMENT ON GERMINATION PERCENTAGE

Cleopatra mandarin

Storage Period	Seed Washing		Seed Drying*		Storage Temperature		Pregermination Treatment		Means
	(1) Not Washed	(2) Washed	(1) Not Dried	(2) Dried 2 hr	(1) 5°C	(2) 25°C	(1) Un-opened Seed	(2) Seed-coat Opened	
(1) Nil	96·6	98·5	97·5	97·7	97·5	97·7	96·2	99·0	97·6
(2) 3 months ..	89·2	88·1	94·9	82·5	96·2	81·1	82·8	94·5	88·6
Means	92·9	93·3	96·2	90·1	96·8	89·4	89·5	96·7	93·1

Significant differences—

Between storage period means (1% level): $1 \gg 2$

Between seed washing treatments: nil

Between seed drying treatments (5% level): $1 > 2$ after 3 months' storage

Between storage temperatures (5% level): $1 > 2$ after 3 months' storage

Between pregermination treatments (1% level): $2 \gg 1$

* 24-hr and 48-hr drying treatments resulted in extremely low germination precentages and were excluded from the analysis

TABLE 10

TRIAL 4: EFFECTS OF PRESTORAGE TREATMENTS, STORAGE CONDITIONS AND PREGERMINATION TREATMENT ON MEAN GERMINATION PERIOD (DAYS)

Cleopatra mandarin

Storage Period	Seed Washing		Seed Drying		Storage Temperature		Pregermination Treatment		Means
	(1) Not Washed	(2) Washed	(1) Not Dried	(2) Dried 2 hr	(1) 5°C	(2) 25°C	(1) Un-opened Seed	(2) Seed-coat Opened	
(1) Nil	15·4	12·7	14·0	14·1	14·2	13·9	16·0	12·1	14·1
(2) 3 months ..	11·6	10·6	9·7	12·5	9·1	13·1	12·5	9·7	11·1
Means	13·5	11·6	11·9	13·3	11·6	13·5	14·3	10·9	12·6

Significant differences—

Between storage periods (1% level): 1⩾2

Between seed washing treatments (1% level): 1⩾2; most pronounced with fresh seed

Between seed drying treatments (1% level): 2⩾1 after 3 months' storage

Between storage temperatures (1% level): 2⩾1 after 3 months' storage

Between pregermination treatments (1% level): 1⩾2

Washed seed germinated more quickly than unwashed seed (Table 10) but this was obvious only in samples tested shortly after extraction from the fruit. Drying at 40°C for 2 hr had little effect on the mean germination period in freshly extracted seed but delayed germination in seed which was stored for 3 months.

Seed which had been stored for 3 months at 25°C germinated more slowly than that held at 5°C. Opening of the seed-coat hastened germination irrespective of other treatment effects.

(e) Trial 5: Effects of Packaging Material, Storage Temperature, Pregermination Treatment and Germination Method

Design.—2 x 2 x 3 x 2 triplicated factorial.

Treatments.—

Packaging Material	Storage Temperature	Pregermination Treatment	Germination Method
Brown paper	5°C	Seed-coat opened ..	Laboratory trays
Polyethylene (·0015 in.) ..	Room temp. (mean 20°C)	Seed-coat unopened ..	Seedbed
		Seed-coat unopened. Seed soaked for 24 hr prior to germination	

Methods.—Emperor mandarin seed was extracted, washed and air-dried until the seed-coat was no longer translucent. It was then dusted with Spergon, packaged as prescribed and stored for 3 months. Room temperature during this period was approximately 20°C. The seed was then subjected to pregermination treatments and germinated either in the laboratory or outdoors in a light sandy loam seedbed.

Duplicate samples were germinated in the laboratory shortly after extraction. Moisture contents of duplicate samples were determined prior to and after storage.

Results.—The moisture content of the seed (55·8%) dropped only slightly during the 3 months' storage period in polyethylene bags. In brown-paper bags, however, the moisture level fell to 6·2% during the same period (Table 11).

TABLE 11

TRIAL 5: EFFECTS OF PACKAGING MATERIAL ON MOISTURE CONTENT OF SEED AFTER STORAGE

Emperor mandarin. Moisture content as percentage of fresh weight

Packaging Material	Prestorage	After 3 Months at 5°C	After 3 Months at Room Temp. (20°C)
Brown paper	55·8	6·2	6·3
Polyethylene		51·9	44·6

The initial laboratory germination records were:—(a) 94% for seed with the seed-coat opened; (b) 89% for unopened seed; and (c) 87·5% for unopened seed soaked in water for 20 hr prior to test.

After 3 months' storage, seed in brown-paper bags had a much lower germination percentage than that stored in polyethylene bags. Separate analyses of the data were therefore carried out for the two packaging materials.

Storage temperature (Table 12) had no significant effect on the viability of seed stored in brown paper, except that germination was improved by soaking the seed for 24 hr prior to test after storage at room temperature. Laboratory germination (Table 13) was higher in seed stored at 5°C than in seed stored at room temperature. The position was reversed in the seedbed. The same set of data indicates that unopened seed and opened seed germinated better in the laboratory than unopened seed soaked in water 24 hr prior to test. On the other hand, unopened seed which had been soaked gave the best performance in the seedbed.

TABLE 12

TRIAL 5: EFFECTS OF PREGERMINATION TREATMENTS ON GERMINATION PERCENTAGE AFTER STORAGE AT 5 AND 20°C

Emperor mandarin. Seed stored in brown-paper bags at initial moisture content of 55·8%.

Pregermination Treatment	Storage Temperature		Means
	(1) 5°C	(2) Room Temp. (20°C)	
(1) Seed-coat opened	14·5	9·8	12·2
(2) Seed-coat unopened	19·2	15·8	17·5
(3) Seed-coat unopened; soaked for 24 hr ..	7·5	11·7	9·6
Means	13·7	12·4	13·1

Significant differences—

Between pregermination treatments (1% level) : 2⩾1,3

Between storage temperature means : nil. When soaked prior to germination, a higher germination percentage was recorded with seed stored at room temperature than with seed stored at 5°C.

TABLE 13

TRIAL 5: EFFECTS OF METHOD OF GERMINATION ON GERMINATION OF SEED STORED IN BROWN-PAPER BAGS AT 5 AND 20°C

Emperor mandarin. Seed stored at initial moisture content of 55·8%.

Germination Method	Pregermination Treatment			Storage Temperature		Means
	(1) Seed-coat Opened	(2) Seed-coat Unopened	(3) Seed-coat Unopened: Soaked 24 hr	(1) 5°C	(2) Room Temp. (20°C)	
(1) Laboratory tray ..	23·5	29·3	10·3	25·4	16·7	21·1
(2) Seedbed	0·8	5·7	8·8	2·0	8·2	5·1
Means	12·2	17·5	9·6	13·7	12·4	13·1

Significant differences—

Between germination methods (1% level) : 1⩾2

Between pregermination treatment means (1% level) : 2⩾1,3

Between storage temperature means : nil

Interactions—

Soaking inhibited laboratory germination but improved seedbed germination.

In the laboratory, seed stored at 5°C germinated better than seed stored at room temperature. The reverse was the case in the seedbeds.

Seed in polyethylene bags (Table 14) had a higher germination percentage after storage at a temperature of 5°C than seed stored at room temperature. Both unopened seed and opened seed germinated better than unopened seed soaked for 24 hr before test. Germination percentages recorded in the laboratory were higher than those recorded in the seedbed.

TABLE 14

TRIAL 5: EFFECTS OF METHOD OF GERMINATION ON GERMINATION PERCENTAGE OF SEED STORED IN POLYETHYLENE BAGS AT 5 AND 20°C

Emperor mandarin. Seed stored at initial moisture content of 55·8%.

Germination Method	Pregermination Treatment			Storage Temperature		Means
	(1) Seed-coat Opened	(2) Seed-coat Unopened	(3) Seed-coat Unopened; Soaked 24 hr	(1) 5°C	(2) Room Temp. (20°C)	
(1) Laboratory tray ..	92·8	95·7	87·8	93·2	91·1	92·1
(2) Seedbed	85·8	85·5	80·3	88·4	79·3	83·9
Means	89·3	90·6	84·1	90·8	85·0	88·0

Significant differences—

Between germination methods (1% level) : 1 ⩾ 2
Between pregermination treatments (1% level) : 1,2 ⩾ 3
Between storage temperatures (1% level) : 1 ⩾ 2

The mean germination periods for seed stored in the two packaging materials in this trial were analysed separately (Tables 15 and 16). With both packaging materials, seed which was opened before test germinated faster than unopened seed irrespective of soaking treatment prior to germination. The mean germination period was less in the laboratory than in the seedbed. Seed in polyethylene bags germinated faster when stored at 5°C than at room temperature. It also germinated much faster than seed stored in brown-paper bags.

TABLE 15

TRIAL 5: EFFECTS OF METHOD OF GERMINATION ON MEAN GERMINATION PERIOD (DAYS) OF SEED STORED IN BROWN-PAPER BAGS AT 5 AND 20°C

Emperor mandarin

Germination Method	Pregermination Treatment			Storage Temperature		Means
	(1) Seed-coat Opened	(2) Seed-coat Unopened	(3) Seed-coat Unopened; Soaked 24 hr	(1) 5°C	(2) Room Temp. (20°C)	
(1) Laboratory tray ..	16·8	24·3	21·6	21·1	20·7	20·9
(2) Seedbed	31·8	39·2	39·3	38·0	35·6	36·8
Means	24·3	31·8	30·4	29·6	28·1	28·8

Significant differences—

Between germination methods (1% level) : 2 ⩾ 1
Between pregermination treatments (1% level) : 2,3 ⩾ 1
Between storage temperature means (1% level) : nil

TABLE 16

TRIAL 5: EFFECTS OF METHOD OF GERMINATION ON MEAN GERMINATION PERIOD (DAYS) OF SEED STORED IN POLYETHYLENE BAGS AT 5 AND 20°C

Emperor mandarin

Germination Method	Pregermination Treatment			Storage Temperature		Means
	(1) Seed-coat Opened	(2) Seed-coat Unopened	(3) Seed-coat Unopened; Soaked 24 hr	(1) 5°C	(2) Room Temp. (20°C)	
(1) Laboratory tray ..	11·9	14·0	12·7	11·3	14·5	12·9
(2) Seedbed	23·7	28·5	27·5	24·3	28·8	26·5
Means	17·8	21·2	20·1	17·8	21·6	19·7

Significant differences—

Between germination methods (1% level) : $2 \gg 1$
Between pregermination treatments (1% level) : $2,3 \gg 1$
Between storage temperatures (1% level) : $2 \gg 1$

(f) Trial 6: Effects of Seed Drying and Fungicidal Treatment

Design.—4 x 3 triplicated factorial.

Treatments.—

Seed Drying	Fungicide
Not dried	No fungicide
Air-dried until seed coat just dry ..	Spergon dust
Air-dried for 6 hr	8-hydroxyquinoline sulphate 1% dip
Air-dried for 24 hr	

Methods.—Emperor mandarin seed was extracted, washed and sponge-dried. The 8-hydroxyquinoline sulphate treatments were applied by this stage and followed by the nominated drying treatments. With the Spergon-treated seed, drying was carried out before the dust was applied. Duplicate samples of 100 seeds were taken from each drying treatment and immediately germinated in the laboratory.

Treatment samples of 100 seeds each were stored at 5°C for 3 months and the unopened seed germinated in the laboratory following a 24-hr soaking in water.

Results.—Table 17 records the laboratory germination percentages shortly after extraction and after 3 months' storage. Drying progressively reduced germination in all treatments except one; 6-hr drying germination percentages were similar to those of seed in which the seed-coat was "just dried." Both of the fungicides improved germination.

TABLE 17

TRIAL 6.: EFFECTS OF AIR-DRYING OF SEED ON GERMINATION PERCENTAGE OF SEED TREATED WITH FUNGICIDES

Emperor mandarin

Prestorage	Seed Drying Treatment	Fungicidal Treatment			Mean Germination after 3 Months
		(1) Nil	(2) Dust	(3) 8-hydroxy-quinoline sulphate Dip	
91·5	(1) Nil	95·3	93·3	92·3	93·7
81·0	(2) Surface dried	65·6	93·3	90·3	83·1
78·5	(3) Dried for 6 hr ..	88·6	85·0	88·0	87·2
70·5	(4) Dried for 24 hr ..	70·9	83·6	82·6	78·7
80·4	Means	79·9	88·8	88·3	85·7

Significant differences—

Between drying treatment means:
5% level 1,3 > 4; 1 > 2,3,4
1% level 1 ⩾ 2,4

Between fungicidal treatment means:
(1% level) 2,3 ⩾ 1

Drying progressively increased the time taken for germination (Table 18). Fungicidal treatments had the same effect. Both drying of the seed and treatment with 8-hydroxyquinoline sulphate increased the percentage of abnormal seedlings (Table 19).

TABLE 18

TRIAL 6: EFFECTS OF AIR-DRYING OF SEED ON MEAN GERMINATION PERIOD (DAYS) OF SEED TREATED WITH FUNGICIDES

Emperor mandarin

Prestorage	Seed Drying Treatment	Fungicidal Treatment			Means
		(1) Nil	(2) Spergon Dust	(3) 8-hydroxy-quinoline sulphate Dip	
12·2	(1) Nil	10·5	11·3	12·6	11·5
10·7	(2) Surface dried	12·5	12·8	13·2	12·8
14·7	(3) Dried for 6 hr ..	14·7	15·4	16·7	15·6
15·1	(4) Dried for 24 hr ..	14·7	16·7	17·8	16·4
13·2	Means	13·1	14·1	15·1	14·1

Significant differences—

Between drying treatment means:
5% level 4 > 3 ⩾ 2 ⩾ 1
1% level 4,3 ⩾ 2 ⩾ 1

Between fungicidal treatment means:
(1% level) 3 ⩽ 2 ⩽ 1

TABLE 19

TRIAL 6: EFFECTS OF AIR-DRYING OF SEED AND FUNGICIDAL TREATMENTS ON PERCENTAGE OF ABNORMAL SEEDLINGS

Emperor mandarin

Prestorage	Seed Drying Treatment	Fungicidal Treatment			Means
		(1) Nil	(2) Spergon Dust	(3) 8-hydroxy-quinoline sulphate Dip	
4·9	(1) Nil	1·3	3·0	5·3	3·2
4·3	(2) Surface dried	5·7	3·7	7·0	5·4
9·6	(3) Dried for 6 hr ..	7·3	9·0	7·3	7·9
10·6	(4) Dried for 24 hr ..	8·7	7·7	11·0	9·1
7·3	Means	5·8	5·8	7·7	6·4

Significant differences—

Between drying treatment means:
5% level 3,4 > 2 > 1
1% level 3,4 ⩾ 1

Between fungicidal treatment means:
(5% level) 3 > 1,2

V. DISCUSSION

In all trials, seed viability decreased and the mean germination period increased as the period of storage increased. The magnitude of these effects was influenced by variety, storage temperature, drying, washing, packaging material, fungicidal treatment and pregermination treatment.

Variety.—Of the varieties tested, Emperor and Cleopatra mandarin seed maintained their viability better than either rough lemon or Joppa sweet orange seed. Rough lemon seed retained its viability quite well for about 6 months and then deteriorated rapidly. Joppa sweet orange seed, on the other hand, deteriorated gradually during the whole of the storage period.

Germination was most rapid in rough lemon, followed by Emperor mandarin, Cleopatra mandarin and Joppa sweet orange in that order. In rough lemon, opening the seed-coat before test had little effect on the mean germination period. With Cleopatra mandarin, Emperor mandarin and Joppa sweet orange, opening the seed-coat before test hastened germination.

Storage temperature.—In general, seed stored best at 5 or 10°C. In Trial 5, however, seed stored in brown-paper bags at room temperature germinated better than seed stored at 5°C irrespective of pregermination treatments such as soaking and/or opening the seed coat.

Seed germinated more quickly after cold storage than after storage at room temperature for the same period. The difference between treatments increased with the time according to the length of the storage period.

Drying.—Drying of the seed after extraction was generally detrimental to viability, even when this treatment was only just sufficient to permit easy handling. It also slowed germination and increased the percentage of abnormal seedlings. The moisture content of the seed should be held above 40% of the fresh weight during the storage period.

Washing.—Washing the seed to remove adhering fruit juice and pulp had no appreciable effect on its storage life. It hastened the germination of fresh seed but not of stored seed.

Packaging material.—Polyethylene was the best of the packaging materials for citrus seed under test. Permeable packaging materials such as brown paper and muslin, which permit the loss of moisture from the seed, proved unsatisfactory. The poor performance of polyvinylchloride and Cellophane as packaging materials may be associated with gas exchange characteristics which affect respiration.

Fungicidal seed dressings.—Spergon and 8-hydroxyquinoline sulphate maintained the viability of the seed better than the other fungicides under test. However, the 8-hydroxyquinoline sulphate treatment delayed germination and produced a relatively high proportion of abnormal seedlings. Spergon also delayed germination but not to the same extent as 8-hydroxyquinoline sulphate.

Pregermination treatment.—The laboratory practice of opening the seed-coat prior to test hastens germination. With fresh seed, the laboratory data from both opened and unopened seed gave a good correlation with seedbed germination. After storage, the correlation held for unopened seed but less so for opened seed.

When seed is stored, both viability and vigour decrease. Vigour of the seed as distinct from viability is probably estimated better when laboratory tests are made with unopened seed. Correlations between laboratory and seedbed germination data were most unsatisfactory when germination percentages were low.

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