spores on the surfaces of healthy fruit but it does not eradicate spores in lesions or inhibit the pathogen once it has invaded the fruit rind (9). When mixed with soil, *G. candidum* is more difficult to eradicate because of the association of the organism with soil debris (5). Much or all of the chlorine is tied up by the soil and organic matter which prevents the chlorine from reacting with fungus propagules. When applied as a spray, higher levels of chlorine would be required to kill the propagules. Higher concentrations of chlorine in a spray could cause atmospheric chlorine to exceed OSHA regulations for worker safety (1). Additional studies are needed to determine efficacy, phytotoxicity, corrosiveness, and levels of chlorine in the worker atmosphere.

Since the effectiveness of chlorine is also dependent upon exposure time, longer periods of wetting of the fruit with chlorine should be more effective. Until recently, however, the fruit reached the washer brushes only a few seconds after receiving the chlorine treatment. The alkaline soap or sodium orthophenylphenate formulations used on washer brushes to wash fruit then inactivated the chlorine. Currently, because of the recent outbreak of canker (3), treatment of fruit with chlorine sprays of 200 μg/ml for 2 *min is mandatory* to eradicate any canker bacterial cells on the surface of fruit (2). It will be necessary to determine how this longer period of exposure to chlorine affects decay control.

Chlorine dioxide is another form of chlorine which could be utilized in Florida packinghouses. The material is not as pH dependent as chlorine and is, reportedly, less corrosive and reactive with organic matter than chlorine (15, 17). Though no comparisons were made here, ClO_2 can be more active than chlorine against microorganisms (4, 7). Stability of ClO_2 is such that the material would need to be generated on site. A system for generating ClO_2 for use in commercial packinghouses could be easily devised (13).

Chlorine is not considered as a fungicide but rather as a disinfectant to reduce inoculum levels of decay pathogens (9). A reduction in the level of inoculum reduces the probability of infection and decay (10, 12). Chlorine could not replace the standard packinghouse fungicide treatment. It should, however, be a required treatment for a soak tank installation and be considered for use in aqueous sprays if decay is a problem (11) to supplement postharvest fungicide treatments for decay control.

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SEASONAL AND TEMPERATURE EFFECTS ON SEED GERMINATION IN STORED GRAPEFRUIT

A. C. Purvis and L. G. Albrigo
University of Florida,
Institute of Food and Agricultural Sciences,
Citrus Research and Education Center,
700 Experiment Station Road, Lake Alfred, FL 33850

Additional index words. Citrus paradisi Macf., abscisic acid, ABA, polyethylene shrink film.

Abstract. **The effects of grove source, harvest date, storage temperature and polyethylene shrink film on seed germination in stored grapefruit were studied for fruit harvested in March, April and May, 1983 and February, March and April, 1984. Numbers of germinated seeds in fruit at harvest increased as the season progressed and was greater for some groves than others. Seeds did not germinate in fruit stored at 10°C for up to 11 weeks but did germinate in fruit stored at 21° and 30°. Sealing the fruit in polyethylene shrink film did not alter the percentage of seeds germinating during storage. Seeds removed from the fruit germinated faster than those in the fruit stored at the same temperature. Abscisic acid at 10^{-4}M inhibited germination of seeds from fruit harvested early in the season but not late season fruit. Harvesting the fruit prior to the time when seeds start to germinate and storing it at temperatures which inhibit**

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germination appear to be the best way to maintain the quality of late season fruit.

Seed sprouting within the fruit is a major problem in marketing late season grapefruit. The germinating seed imparts an undesirable off-flavor to the entire fruit, making it unsuitable for the fresh market as well as for processing (1). Although seedless varieties have been developed for the fresh market, they still contain as many as 4 to 6 viable seeds per fruit and one germinated seed can lead to off-flavors. Citrus seeds can germinate in the fruit while they are still on the tree and during postharvest storage (1, 2). However, germination generally does not occur until April or May after bloom and the spring flush of growth has begun (2). The factors responsible for precocious germination of grapefruit seed are not known.

The rate and percentage germination of citrus seeds in nurseries is influenced by temperature, with the highest percentage germination occurring between 26° and 33°C (3, 6). Presumably, seed within the fruit also respond to temperature. Fruit maturity, phytohormone levels and environmental factors other than temperature may also influence the precocious germination of grapefruit seeds (6).

The objective of this study was to determine the effect of storage temperature and harvest date on the germination of seeds in stored grapefruit. Fruit were harvested from 3 groves for the 1983 storage studies and from 3 different groves for the 1984 studies. Since sealing grapefruit in polyethylene shrink film is being investigated as a method for extending the storage life of grapefruit, the effect on seed germination was also examined.

Materials and Methods

'Duncan', 'Marsh', and Ruby Red grapefruit (*Citrus paradisi* Macf.) were harvested from one Interior grove and two Indian River groves for the 1983 studies. 'Marsh' grapefruit were harvested from one Interior grove and two Indian River groves for the 1984 studies. The fruit were harvested on 3 dates each year. Some fruit were cut at harvest and the seeds were removed and examined to observe any germination which had already occurred. The extracted ungerminated seed were then used to test for germination potential. The remaining fruit were washed and treated with benomyl (600 μg ml^{-1}) to reduce decay by fungal pathogens. The fruit were then waxed with a solvent wax and/or were sealed individually in polyethylene shrink film (21.1 μm in thickness) to reduce moisture loss during storage. The fruit were then placed in fiberboard cartons and stored at temperatures ranging from 5 to 30°C. Vapor pressure deficits in the storage rooms ranged from 0.44 to 6.36 mbars. At the end of the storage period, the fruit were cut and the seeds were removed and counted. Seeds with split seed coats were classified as germinating. Only sound fruit were examined for seed germinations.

The ungerminated seeds removed at each harvest were rinsed in distilled water, soaked for 5 min in a 1% NaOCl solution, and dusted with thiram powder. The seed were then wrapped in two paper towels saturated with distilled water, 10^{-4} M abscisic acid (ABA) or filtered grapefruit juice and placed in open polyethylene bags. For the 1983 studies, germination was carried out in laboratory drawers at room temperature (21-25°C) for 4 to 6 weeks. For the 1984 studies, germination was carried out in the storage rooms with the fruit. Final germination was recorded after 6 to 9 weeks.

Results

1983. There were no germinated seeds in the 'Duncan' grapefruit harvested on April 1, 1983 and seeds did not germinate in fruit stored for 80 days at 5° or 10°C (Table 1). Only a few seeds germinated in fruit stored at 15° or 21°C but several seeds germinated in fruit stored for 80 days at 30°C. Fruit waxed and sealed in polyethylene shrink film had fewer germinated seed than did waxed unsealed fruit.

Table 1. Seed germination in waxed 'Duncan' grapefruit harvested on April 1, 1983 from an Interior grove. Some of the fruits were sealed in polyethylene shrink film. The fruit were stored for 80 days at various temperatures.

Storage temperature (°C)	Number of seeds		Germination (%)	
	Sealed	Unsealed	Sealed	Unsealed
5	332	352	0	0
10	410	320	0	0
15	362	336	0.3	0.9
21	350	495	0	2.5
30	405	539	6.4	26.7

One lot of the seedless grapefruit in the 1983 study had a small percentage of germinated seed when harvested March 31-April 4, whereas the other lot did not (Table 2). Fruit from the latter grove had 18% of the seeds germinated in a second lot of fruit harvested 7 weeks later on May 25. The extracted seed from all lots germinated readily in warm, moist conditions within 4 to 6 weeks. ABA inhibited seed germination only in lot B where no germination was

Table 2. Germination of seeds extracted from or in grapefruit harvested from Indian River groves during 1983. Storage was at room temperature (21-25°C).

Date harvested	Cultivar	Grove	Treatment	Seed Germination (%)		
				At harvest	After storage 4 wk	After storage 6 wk
Mar.	Ruby Red	A	Extracted + H_2O[z]	4	48	—
			Extracted + ABA	—	38	—
			In fruit	—	—	51
Apr.	Marsh	B	Extracted + H_2O[y]	0	59	93
			Extracted + ABA	—	7	7
			In fruit	—	—	37
May	Marsh	B	Extracted + H_2O[x]	18	80	95
			Extracted + ABA	—	65	93
			In fruit	—	—	44

[z]21 seeds per treatment, no replications.
[y]45 seeds per treatment, no replications.
[x]40 seeds per treatment, no replications.

detected at harvest. One-third to 1/2 of the seeds germinated in the fruit during storage for 6 weeks at room temperature.

1984. Location of the grove during the 1984 test had a large influence on the germination of seeds. Fruit harvested from the Interior grove had higher percentages of germinated seeds at harvest and following 11 weeks storage than did the fruit harvested from the Indian River groves (Fig. 1). Fruit harvested from the Interior area grove on March 5 and April 16, 1984 had 33% and 53% of their seeds germinated at harvest, respectively (Fig. 1 and Table 3). In contrast, no germinated seed were detected in fruit from the Indian River groves at harvest. Fruit harvested from the Indian River groves on February 12, 1984 also had low percentages (less than 10%) of germinated seeds after 11 weeks storage at 21° or 30°C (Fig. 1). No seeds germinated in fruit harvested from any grove on February 12 and stored at 10°C. The percentage of seeds germinating during storage tended to increase with later harvest date for fruit from all 3 groves. The germinated seeds in fruit from the Interior grove stored at 10° were seeds which had already germinated in the fruit prior to harvest. Sealing unwaxed 'Marsh' grapefruit in polyethylene shrink film had no consistent effect on seed germination.

Although low percentages of the seeds germinated during storage in the fruit harvested from the Indian River groves in 1984, comparable seeds removed from fruit at harvest had high percentage germination in moistened paper at 21° and 30°C. However, extracted seeds did not germinate at 10°C (Table 3). As observed in the 1983 studies, ABA at 10^{-4} M inhibited germination of extracted seed only for earlier harvests in 1984. Grapefruit juice did not appear to inhibit germination although excess moisture and mold growth in the juice-treated seeds from the first harvest reduced or stopped germination.

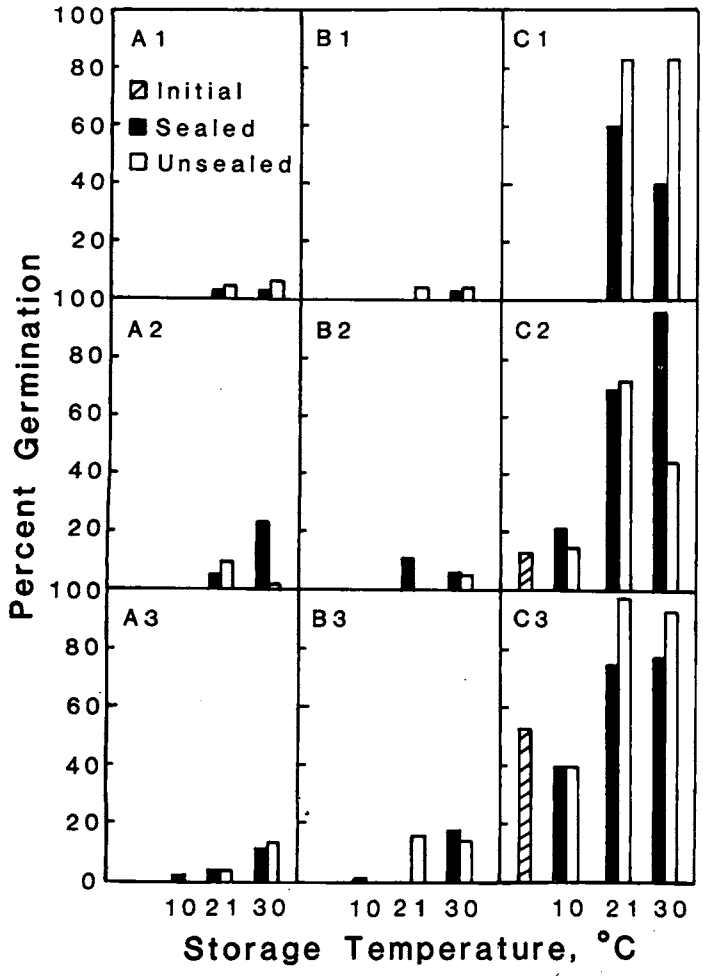

Fig. 1. Percentage of seeds germinated in 'Marsh' grapefruit stored for 10 weeks at 10°, 21°, or 30° C from two Indian River groves (A and B) and one Interior grove (C) harvested on 3 dates (1) February 12, 1984, (2) March 5, 1984, and (3) April 16, 1984. (/), seeds germinated at harvest. ■, fruit sealed in polyethylene shrink film. □, unsealed fruit.

Table 3. Germination of seeds removed from 'Marsh' grapefruit in paper towels moistened with 10^{-4} abscisic acid (ABA), grapefruit juice, or water and held at 10, 21, or 30°C.

Storage treament	Extracted seed (% Germination) Harvest dates 13 Feb. 84			5 Mar. 84			16 Apr. 84		
	A[z]	B	C	A	B	C	A	B	C
Initial germination	0	0	0	0	0	33	1	0	53
10°C + H_2O	0	0	0	0	0	0	0	0	0
21°C + H_2O	100	100	100	83	100	100	100	100	100
30°C + H_2O	87	100	100	100	100	100	100	100	100
30°C + 10^{-4} M ABA	0	0	0	7	68	72	50	65	100
30°C + grapefruit juice	0	44	100	83	100	100	100	100	97
Total seeds/treatment	34	41	26	60	60	32	90	85	33
Storage time (wk)	7	7	7	9	9	9	6	6	6
Wetting solution (ml)	50	50	50	25	25	25	25	25	25

[z]A = Outer river district; B = Indian River district = B of 1983; C = Interior Grove.

Discussion

Germination is defined as the resumption of embryo growth following a period of quiescence or dormancy imposed by internal and/or environmental factors. Since grapefruit seedlings cease to grow when the diurnal minimum temperature decreases to 9-10°C (7), it is not surprising that seeds do not germinate in grapefruit stored at low temperatures. The high percentage of germinated seeds in late harvested (April) grapefruit stored at 10°C represents germination prior to harvest rather than during storage. A previous report of germinated seeds in fruit after storage at 5°C and 13°C (2) was probably also a case of germinated seeds in the fruit at harvest.

Higher diurnal air temperatures may promote increased seed germination in fruit as the season progresses since removal of the seed from the fruit promoted their germination at temperatures above 20°C. However, factors other than temperature also affect germination of seeds in grapefruit.

The high percentage of germination of the seed in grapefruit harvested from the Interior grove in 1984 is quite different from the Indian River groves. The Interior experienced a freeze in December 1983 and although the test grove from this area escaped severe damage, i.e. the trees did not defoliate, the fruit were exposed to temperatures below freezing for several hours. Whether these temperatures subsequently influenced germination is not known. Mobayen (5) reported faster rates and shorter time spans of germination for seeds extracted from trifoliate orange fruit at various stages of development and stored at 4.5°C for 12 weeks before germination at 25°. Thus, low temperatures may hasten the breakdown of inhibitors (6) so that germination proceeds rapidly at favorable temperatures.

Moisture is required for seed germination and alternatively, the juice released from the freeze-damaged segments may have provided moisture or some other component which stimulated seed germination in fruit prior to harvest. The ineffectiveness of ABA to inhibit germination of seeds removed from the late harvested fruit may be due to the seeds

having reached an irreversible stage of germination in the fruit.

Sealing fruit in polyethylene shrink film does not appear to have any significant effect on germination. The reduction in percentage germination in the 1983 study may have been due to an additive effect of wax and polyethylene film on gas exchange. The combination of the two can create anaerobic conditions causing the fruit to produce ethanol especially at high storage temperatures (4). Whether high ethanol inhibits citrus seed germination is not known but high CO_2 apparently does inhibit germination (5). High seed numbers in 'Duncan' grapefruit may have contributed to a potentially high CO_2 level in the fruit sealed in polyethylene shrink film. In this study, neither internal quality of the fruit nor internal CO_2 concentration during storage was evaluated.

Results of this study clearly show the tendency of seeds to germinate in the fruit as harvest is extended during the spring. Furthermore, the tendency for seeds to germinate within the fruit varies with grove location and from season to season. From a fruit quality standpoint, grapefruit intended from storage and delayed marketing should be harvested prior to the time when seeds start to germinate and stored at temperatures which inhibit germination.

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ECONOMICS OF WEIGHT BAGGING MACHINES FOR FLORIDA CITRUS PACKINGHOUSES[1]

R. P. Muraro and W. F. Wardowski
University of Florida, IFAS,
Citrus Research and Education Center,
700 Experiment Station Road,
Lake Alfred, FL 33850

Abstract. **Weight bagging machines have been introduced to Florida's fresh citrus packing industry. With the high investment cost of these machines, the question arises as to what will be the payback period for the investment cost. To answer this question, labor and material costs and the additional fruit packed from weight savings are compared to the conventional packer's aid method of bagging fresh citrus fruit. Four seasonal volume packs of bag master cartons—25,000, 50,000, 100,000, and 200,000—are used in the analysis. Assuming a 100% machine efficiency for the mesh-net bags, the break-even periods are 5.64, 2.82, 1.41, and 0.70 yr, respectively, whereas mesh-net bag and poly bag packed in equal volumes the break-even periods are 10,59, 5.29, 2.65, and 1.32 yr. When the savings from increased fruit bagged and packed are added, the break-even periods assuming a 100% machine efficiency are 3.03, 1.51, 0.76, and 0.38 yr for the mest-net bag and 4.79, 2.40, 1.20, and 0.60 yr for the mesh-net bag and poly bag packed in equal volumes.**

Florida's fresh citrus packing industry is labor intensive. From discussions with citrus packers, the authors have found that the use of packer's aids reduced labor requirements from an average of 5 workers to 4 workers per equal volume of citrus fruit packed. Labor costs have increased due to higher minimum wage rates, workmen's compensation insurance, incentive piece rates, and other fringe benefits. Thus labor saving equipment is becoming an increasingly important consideration.

With respect to bagging fresh citrus fruit, an additional cost has been incurred by the packer due to an excess fruit weight being packed per bag. For this paper, the standard 5 lb. size fruit bag was used. A 1979-80 season survey indicated that the average weight for bagged oranges, all sizes, was 5 lb. and 11 oz (Florida Citrus Mutual, 1980, unpublished). According to a 1978 study on automatic weighing equipment (1), the preferred weight per bag for fresh citrus fruit that would allow shrinkage before shipping would be 5 lb. 4 oz.

Weight bagging machines are one possible alternative to reducing labor and material costs and providing a more accurate weight count for bagged fruit. This paper will explore the payback period of a typical machine.

Analysis

During the spring of 1984, the authors visited 2 fresh citrus packinghouses to observe the only weight bagging machine being used by Florida citrus packers. Time requirements for weighing, bagging, packing a pallet equivalent of bagmaster cartons, and labor requirements for the weight bagging machine were recorded. Likewise, the authors, through discussions with commercial citrus packers, obtained information on the labor and cost requirements using the conventional packer's aid. Bag material costs and equipment prices were obtained from the manufacture of the weight bagging machines which we observed. [*Note*: During the 1983-84 fruit season, one manufacturer (Tomac Corporation, Woburn, Massachusetts) had machines in operation for Florida citrus.]

Data and Results

Table 1 presents the list price for the weight bagging machine which the authors observed. The cost for a machine with mesh-net bags capability is $69,000. An additional cost of $23,000 would allow poly bags to be

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