with bushy branching dominant to sparse branching. It appears reasonable to suggest that *C. cauliflora* possesses strong apical dominance, while *C. monoica* has weak apical dominance.

Literature Cited

1. Angell, F. F. and W. H. Gabelman. 1970. Inheritance of purple petiole in carrot, *Daucus carota* var. *sativa*. *HortScience* 5:175.
2. Culp, T. W. 1960. Inheritance of paper shell capsules, capsule number and plant color in sesame. *J. Hered.* 51:146-148.
3. Erickson, H. T. and F. A. A. Couto. 1963. Inheritance of four plant and floral characters in Okra (*Hibiscus esculentus* L.). *Proc. Amer. Soc. Hort. Sci.* 83:605-608.
4. Gupta, B. D., and M. S. Sarma. 1954. The genetics of *Corchorus* (jute) VI. Inheritance of a new pigmentation pattern in *Corchorus capsularis*. *J. Genet.* 52:374-382.
5. Hofmyer, J. D. J. 1938. Genetic studies of *Carica papaya* L. *So. Afr. Dept. Agr. and For. Sci. Bul.* 187. 64 p.
6. Ito, P. J. and H. Y. Nakasone. 1968. Compatibility and the inheritance of a seedling character in guava (*Psidium guajava*). Proc. *Trop. Reg., Amer. Soc. Hort. Sci.* 12:216-221.
7. Mekako, H. U. and H. Y. Nakasone. 1975. Floral development and compatibility studies of some *Carica* species. *J. Amer. Soc. Hort. Sci.* 100:145-148.
8. _____ and _____ . Interspecific hybridization among 6 *Carica* species. *J. Amer. Soc. Hort. Sci.* (In press)
9. Park, S. J. and P. P. Rotar. 1968. Genetic studies in Spanish clover, *Desmodium sandwicensis* E. Mey. I. Inheritance of flower color, stem color, and leaflet markings. *Crop Sci.* 8:467-470.
10. Scott-Moncrief, R. 1936. A biochemical survey of some Mendelian factors for flower color. *J. Genet.* 32:117-170.
11. Storey, W. B. 1941. Papaya production in the Hawaiian Islands; Part I: The botany and sex relationship of the papaya. *Hawaii Agr. Expt. Sta. Bul.* 87 p. 5-22.
12. _____. 1969. Pistillate papaya flower: A morphological anomaly. *Science* 163:401-405.
13. Warmke, H. E., E. Carbanillas, and H. J. Cruzado. 1954. A new interspecific hybrid in the genus *Carica*. *Proc. Amer. Soc. Hort. Sci.* 64: 284-288.

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Colonization of Almond by *Aspergillus flavus*[1]

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Abstract. **The *Aspergillus flavus* group was associated with both sound and insect damaged kernels of almond *Prunus dulcis* (Mill.) D.A. Webb during 1972 and 1973. About 1 of 2,000 sound kernels and 1 of 200 insect damaged kernels were colonized. Surface contamination was common on sound and damaged kernels. In orchard plots, spores inoculated on the fruit colonized hulls, shells, and kernels of maturing almonds. Aflatoxins were detected in harvested kernels and hulls. Almond fruits were susceptible to colonization from the time of hull-split, when rapid drying of the fruit began, until after harvest when moisture of the kernel dropped below about 5% based on the fresh weight of the kernel. Infestations by the navel orangeworm, *Paramyelois transitella* (Walker), increased colonization of the kernels by *A. flavus* from experimental plots.**

The drupe of the edible sweet almond has a distinct pericarp enclosing the kernel. This pericarp consists of an outer fleshy hull and inner hard shell. Fruits usually mature on the tree, and a longitudinal suture on one side of the hull splits exposing the shell, allowing rapid drying of the fruit. Cultivars vary in shell thickness and dehiscense (20).

Drying fruits are shaken onto the ground, picked up mechanically, transported to a location where the hulls are removed, and sent tot a plant for shelling, storing, and processing.

Many kinds of micro-organisms are found on almonds (12, 13, 14, 18) and may colonize the hull while the fruit is on the tree (14) or on the ground (12, 13).

Toxigenic species of *Aspergillus* are widespread on seed and other crops (8, 9, 10). *Aspergillus flavus* is a "group" species (16) containing 11 species. *A. flavus* Link, and *A. parasiticus* Speare both are included in this group and may produce toxic metabolites called aflatoxins. In the Central Valley of California, where most almonds are produced in the U.S., fungi in the *A. flavus* group occurs sporadically on cotton (2). Of 345 objective samples of almonds taken in the period 1970-1974, 8% had detectable aflatoxins at the average level of 20 μg/kg total aflatoxins and a range of 2-84 μg/kg (Dr. L. Stoloff, Food and Drug Admin., personal communication). These fungi may colonize almonds while they are drying on the tree or soil (6) and might lead to a pre- or postharvest invasion of kernels by *A. flavus* and contamination by aflatoxins. Preliminary information (Harry W. Schroeder, USDA, College Station, Texas, unpublished report) indicated *A. flavus* occurred on insect-damaged almonds more frequently than on sound nuts. We studied the susceptibility of the almond fruit to *A. flavus* colonization with emphasis on the role of the navel orangeworm (NOW) that commonly damages both kernel and hull.

Materials and Methods

Analysis for Aspergillus flavus. Surface disinfested and non-disinfested almond kernels, shells, or hulls were tested for presence of the *A. flavus group.* For surface disinfestation, samples were dipped in 70% (v/v) ethanol/H_2O for 10 sec, then immediately soaked in 0.5% sodium hypochlorite solution for 5 min. Without further washing, samples were then aseptically placed on plates of malt-salt medium (MSM) containing 7.5% NaCl, 2% malt extract and 2% agar. Non-disinfested samples were plated directly on MSM plus 13 μg/ml 2,6-dichloro-4-nitroaniline to inhibit growth of some *Rhizopus* spp. Five almond kernels or 5 half-shells, or 5 half-hulls were placed on each plate. After incubation for 1 week at 30°C, colonies of *A. flavus* were

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counted. Most cultures were identified as *A. flavus* group by color. Representative cultures were compared to known isolates of *A. flavus* growing on MSM and usually were identified as either *A. flavus* Link or *A. parasiticus* Speare (16).

Analysis of aflatoxins. Aflatoxins were determined in hulls by the method of Pons et al. (15) with slight modification, and in kernels by the method of Robertson et al. (17) with a slight modification (M. Uota, unpublished). The amount of aflatoxin B_1 was estimated visually on the thin layer chromatogram.

Sampling of commercial almonds. During 1972 and 1973, 215 samples of almond kernels were obtained from commercial growers and handlers in California. Sampling began about July 15 and continued until the end of the storage season in May or June. In the laboratory, kernels were sorted into insect damaged and sound kernels. The samples, from various geographic locations in California, ranged in size from 50 to 400 sound kernels and from 5 to 50 insect-damaged kernels.

Inoculation of almond fruit with A. flavus before harvest. By the technique of Ashworth et al. (5), we introduced eggs of NOW and conidia of *A. flavus* into paper or cloth bags that enclosed 2 almond fruits attached to the tree. Five eggs of NOW were introduced onto each fruit on small pieces of paper. Dry conidia were blown toward the surface of the fruit with a powder blower. Conidia were from five 1-week old cultures of the *A. flavus* group isolated from almond kernels and shown to be toxigenic, and the NOW eggs (3-4 days old) were from laboratory-reared insects. The eggs generally hatched within 24 hr after being placed on the fruit. Specific techniques used in 1972 or 1973 orchard tests are presented in the results.

Results

Occurrence of A. flavus in commercial almond samples. One hundred seventeen samples consisting of 12,580 sound kernels and 2,960 insect-damaged kernels in 98 samples were analyzed for *A. flavus*. *A. flavus* was found 10 times as often in insect-damaged kernels as in sound kernels when both were surface disinfested (Table 1). Surface contamination occurred in both insect-damaged and sound kernels, but again, more frequently on insect-damaged kernels (Table 1).

Twenty-seven isolates of *A. flavus* from the surface-disinfested kernels were screened for aflatoxin production. Twenty-one of the isolates produced detectable amounts of aflatoxin on a medium of sterile rice or almonds when incubated for 5-7 days at 30°C.

Table 1. Amount of *Aspergillus flavus* associated with almond kernels in samples collected from growers and handlers in 1972 and 1973.

Sample type	Surface-disinfested[z]	Total kernels examined	Total samples examined[y]	*A. flavus* colonization (%)	
				Kernels	Sample
Insect-damaged	No	540	45	58	100
	Yes	2,420	53	0.6	17
Sound	No	1,880	34	47	100
	Yes	10,700	83	0.06	7

[z]Kernels dipped in 70% ethanol for 10 sec followed by 0.5% sodium hypochlorite solution for 5 min.

[y]Samples contained 50-400 sound kernels, or 5-50 insect damaged kernels.

Inoculation of almond fruit with A. flavus in the orchard. In 1972, 'Kapareil' soft shelled almond trees, located near Clovis, California were selected for a test plot. Treatments were arranged in a split plot design of 4 random blocks of 4 treatments applied at 3 stages of growth of the fruit (20 fruit/sample). Representative fruit was selected for all treatments on May 18. At this time fruits to be bagged were washed with 0.01% sodium hypochlorite solution and covered with paper bags. The treatments were applied: 1) before hull split, June 1; 2) at the time 50% of the hulls had split, June 29; and, 3) 2 weeks before harvest, July 20. Treatments of fruit were: 1) bagged fruit infested with NOW and *A. flavus*, 2) bagged fruit infested with *A. flavus* alone, or 3) non-infested bagged fruit, and 4) non-infested, non-bagged fruit.

Surface-disinfested hulls, shells and kernels were analyzed for *A. flavus* 2 weeks after each inoculation and again after 2 months of storage. After harvest, all samples were fumigated with 24 g of methyl bromide/m^3 at 18°C for 24 hr to eliminate insects and then held in dry storage until the final analysis. The methyl bromide did not eradicate spores of *A. flavus* on paper strips fumigated with the almonds and did not appear to affect the final analysis.

Almond fruits were not colonized by *A. flavus* before the hulls split open on the tree. Although part of the sample inoculated before hull split was lost due to laboratory contamination,

Table 2. Analysis of *Aspergillus flavus* in 'Kapereil' almond fruits from a 1972 experimental field plot, 2 weeks after inoculation.

Time of inoculation	Part of fruit	% colonization of fruit after indicated field treatments[z]				
		Uncovered control	Covered[y] control	Fungus[x] introduced and covered	Fungus and worm[w] introduced and covered	Overall mean for inoculation time
At 50% hull split (June 29, 1972)	Kernels	0	0	0	0	0
	Shells	8	0	15	20	11
	Hulls	0	0	35	53	22a
2 weeks before harvest (July 20, 1972)	Kernels	0	0	3	10	3
	Shells	0	8	3	8	4
	Hulls	0	8	65	65	34b
Overall Means						
	Kernels	0	0	1.3	5.0	
	Shells	3.3	3.3	8.8	13.7	
	Hulls	0b	3.3b	50.0a	58.8a	

[z]Statistical analysis indicated significant differences only in hulls. Overall hull means within a row or column without a letter in common differ at the 95% confidence level. Each datum represents *A. flavus* isolated from 10 surface disinfested fruit parts replicated 4 times.

[y]Fruits of 'Kapereil' were covered with a paper bag to allow controlled inoculation and to reduce contamination.

[x]Inoculated with conidia from 5 toxigenic isolates of *A. flavus* from kernels.

[w]Eggs of the navel orangeworm were placed on the fruit at the time of inoculation.

Table 3. Analysis of the *Aspergillus flavus* in 'Kapareil' almond fruits from a 1972 experimental field plot 2 months after harvest.

Time of inoculation	Part of fruit	% colonization of the fruit after indicated field treatments[z]				
		Uncovered control	Covered[y] control	Fungus[x] introduced and covered	Fungus and worm[vw] introduced and covered	Overall mean for inoculation time
2 weeks before hull split (June 1, 1972)	Kernels	5	5	65	57	33a
	Shells	0	0	40	47	44a
	Hulls	0	5	100	93	49a
At 50% hull split (June 29, 1972)	Kernels	0	5	35	85	31a
	Shells	0	0	12	50	31a
	Hulls	12	0	95	98	51a
2 weeks before harvest (July 20, 1972)	Kernels	3	0	30	40	18b
	Shells	3	0	8	20	10a
	Hulls	3	0	98	85	46a
Overall Means						
	Kernels	3c	3c	43b	61a	
	Shells	1a	0a	20b	39c	
	Hulls	5a	2a	98b	92b	

[z]Statistical analysis indicated significant differences as shown for the overall means. Overall means from a fruit part within a row or column without a letter in common differ at the 95% confidence level. Each datum represents the *A. flavus* isolated from 10 surface disinfested fruit parts replicated 4 times.

[y]Fruits of 'Kapareil' were covered with a paper bag to allow controlled inoculation and to reduce contamination.

[x]Inoculated with conidia from 5 toxigenic isolates of *A. flavus* from kernels.

[w]Eggs of the navel orangeworm were placed on the fruit at the time of inoculation.

[v]Samples were fumigated after harvest with 24 g of methyl bromide/m^3 for worm control.

samples were taken from adjacent trees as an attempt to evaluate the colonization before hull-split; these yielded no *Aspergillus* when surface-disinfested. After the hulls had split, the hulls, and to a lesser degree the shells and kernels, were rapidly invaded by many *Aspergillus* spp., including *A. flavus*. Two weeks after inoculation, a high percentage of the hulls were colonized by *A. flavus* (Table 2). Two months after harvest, the percentage of *A. flavus* had increased in hulls, shells and kernels, indicating that activity of the fungus continued after harvest (Table 3).

After foraging on the fruit for 2 weeks, NOW only slightly increased colonization by *A. flavus* (Table 2), however, 2 months after harvest NOW had significantly increased the incidence of *A. flavus* in shells and kernels (Table 3). The fruits were susceptible to colonization with or without worm damage from the period of hull split until some time after harvest.

Fruit became susceptible to infection when the hulls split and the fruit moisture content was about 80% (Fig. 1). At harvest, the kernels, shells, and hulls had 7, 15, and 23% moisture, respectively. These represent moisture levels in equilibrium with 80% RH at 24°C as determined by 4 tests in which kernels were held over saturated salt solutions for 1-2 months (19) (Fig. 2). Fungal activity probably would continue until a moisture level in equilibrium with 70% RH at 24° was reached or about 5% moisture in the kernels (11).

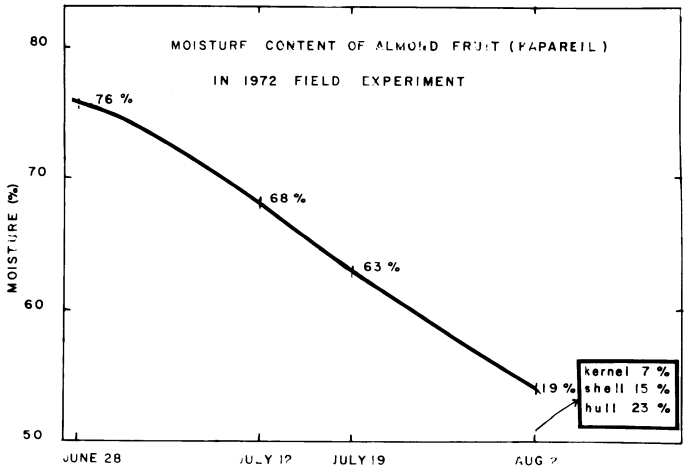

Fig. 1. Moisture content based on the fresh-fruit wt of whole almond fruit on the tree from the time of hull-split until the fruit was removed from the tree at normal harvest time. The data are from an orchard used in a field test in 1972, and each point represents a sample of 10 fruits taken from untreated control trees.

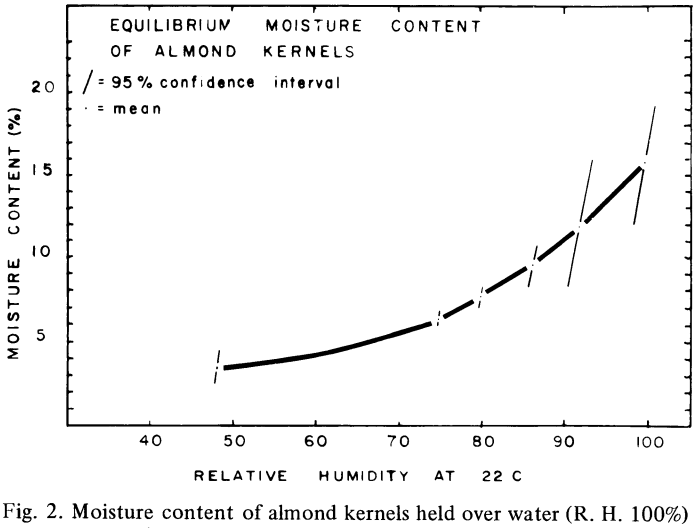

Fig. 2. Moisture content of almond kernels held over water (R. H. 100%) or saturated solutions of $NH_4H_2PO_4$, K_2CrO_4, $(NH_4)_2SO_4$, NaCl, or KNO_2 respectively 92, 86, 80, 75, 48% RH at 22° for 1-2 months. Each point represents the average of 4 tests with 50 g of whole almond kernels. Moisture content is the oven dry wt (96 hr at 86°C)/wet x 100.

Table 4. Aflatoxins in 'Kapareil' almond fruits from an experimental field plot 2 months after harvest.

Part of fruit	% of samples containing aflatoxin and range of the concn in fruits after indicated field treatments[z]: Uncovered control %	μg/kg	Covered[y] control %	μg/kg	Fungus[x] introduced and covered %	μg/kg	Fungus and worm[vw] introduced and covered %	μg/kg
Kernels	0	0	0	0	17	(0-50)	17	(0-335)
Hulls	0	0	8	(0-51)	92	(0-1290)	92	(22-520)

[z]Each datum represents 12 assays of the hull or kernels from 10 fruits.

[y]Fruits of 'Kapareil' were covered with a paper bag to allow controlled inoculation and to reduce contamination.

[x]Inoculated with conidia from 5 toxigenic isolates of *A. flavus* obtained from kernels.

[w]Eggs of the navel orangeworm were placed on the fruit at the time of inoculation.

[v]Samples were fumigated after harvest with 24 g of methyl bromide/m^3 for worm control.

Table 5. The colonization of kernels from the fruit of 7 almond cultivars inoculated with conidia of *Aspergillus flavus* at a time when 10 to 50% of the hulls had split open.

Almond cultivar	% kernels colonized by *A. flavus*[z]	No. of trees sampled[y]
Seedling #1	31	1
Seedling #2	57	1
Vesta	63	1
Davey	53	1
Nonpareil	22	5
NePlus	23	2
Mission	2*	5

*Considered to be different from other data in the column.

[z]Almond fruit were inoculated at hull split while on the tree and covered with muslin bags to protect the fruit from contamination and worm infestation.

[y]20 inoculated kernels and 20 non-inoculated kernels from each tree were surface disinfested and plated on malt-salt agar medium. *A. flavus* was not found in isolations from non-inoculated fruits.

Aflatoxin was found in the inoculated kernels and hulls 2 months after harvest. NOW infestations did not increase the occurrence or quantity of aflatoxin in this test (Table 4).

In 1973, unwashed almond fruits from 'Nonpareil', 'NePlus', 'Davey', 'Mission' (TX), 'Vesta', and 2 unnamed trees, grown at Fresno State University or at the Univ. of California, Kearney Field Station were enclosed in muslin bags and inoculated with *A. flavus* at the time of 10-50% hull split. No NOW were placed on the fruit and worm damage was not found in the test fruit. 'Mission' apparently was less susceptible to invasion by *A. flavus* than other cultivars tested. Some kernels of all the cultivars were infested (Table 5) and these tests confirmed the 1972 test with 'Kapareil', indicating that kernels can be colonized without insect damage to the fruit.

Discussion

Fungi, including *Aspergillus* may invade the split almond hull. We found *A. flavus* on drying hulls on non-inoculated almond fruits on the tree in commercial orchards. The low frequency of the fungus found in surface-sterilized commercial samples of sound nuts contrasts with the high frequency of kernel colonization of inoculated fruits. The low frequency of *A. flavus* in commercial samples may be due to low inoculum densities in California almond orchards or to the effect of other micro-organisms that are antagonistic to the *A. flavus* group, or to environmental conditions not found in our inoculated field tests.

The moisture content of the fruit influences growth of the fungus (2, 4, 9). We found an initially high moisture content at the time of hull split; the moisture then fell to a level that might restrict growth. This point may be at or below 5% moisture by weight in the kernel, but the exact moisture content at which fungal growth ceases may vary with temperature (7) or oil content of the kernel (8) and has not been established by this study. Because drying might be delayed or bagged or covered fruit, the time of susceptibility might have been prolonged.

The soft shelled commercial cultivars do not appear to provide a marked barrier to invasion by *A. flavus*. The increase of *A. flavus* associated with insect-damaged nuts in commercial samples, and in worm-infested test samples may not only result from opening the shell and exposing the kernel to air-borne inoculum, but NOW larvae foraging in the hulls might encounter *A. flavus* colonies and carry the fungus to the kernel. In addition, NOW might increase the period of susceptibility of the kernels by increasing the available moisture, through respiration, in the areas of the kernel where the larva is burrowing.

The colonization of hulls and kernels of almonds by *A. flavus* and the subsequent production of aflatoxin suggest a potential hazard. The low frequency of the fungus in sound kernels, as compared with insect damaged kernels, suggests that the number of contaminated nuts could be reduced by effective control of navel orangeworm and other insects.

Moisture content and insect damage are important factors in preharvest colonization of almond hulls and cotton bolls (1, 2, 3, 4). Consequently, cultural practices that promote rapid drying of the almond fruit on the tree may inhibit mold development and toxin production.

Literature Cited

1. Ashworth, L. J., Jr., and R. B. Hine. 1971. Structural integrity of the cotton fruit and infection by microorganisms. *Phytopathology* 61: 1245-1248.
2. _____, J. L. McMeans, and C. M. Brown. 1969. Infection of cotton by *Aspergillus flavus:* epidemiology of the disease. *J. Stored Prod. Res.* 5:193-202.
3. _____, _____, and _____. 1969. Infection of cotton by *Aspergillus flavus:* time of infection. *Phytopathology* 59:383-385.
4. _____, _____, and _____. 1969. Infection of cotton by *Aspergillus flavus:* the influences of temperature and aeration. *Phytopathology* 59:669-673.
5. _____, R. E. Rice, J. L. McMeans, and C. M. Brown. 1971. The relationship of insects to infection of cotton bolls by *Aspergillus flavus. Phytopathology* 61:488-493.
6. _____, H. W. Schroeder, and B. C. Langley. 1965. Aflatoxins: environmental factors governing occurrence in Spanish peanuts. *Science* 148:1228-1229.
7. Bonner, J. T. 1948. A study of the temperature and humidity requirements of *Aspergillus niger. Mycologia* 40:728-738.
8. Christensen, C. M. 1957. Deterioration of stored grains by fungi. *Bot. Rev.* 23:108-134.
9. _____, and H. H. Kaufmann. 1965. Deterioration of stored grains by fungi. *Annu. Rev. Phytopath.* 3:69-84.
10. Duggan, R. E. 1970. Controlling aflatoxins. *FDA Papers April 1970.* p. 13-18.
11. Griffin, D. M. 1963. Soil moisture and the ecology of soil fungi. *Biol. Rev.* 38:141-166.
12. King, D. A., Jr., M. J. Miller, and L. C. Eldridge. 1970. Almond harvesting, processing, and microbial flora. *Appl. Microbiology* 20:208-214.
13. Kokal, D., and D. W. Thorpe. 1969. Occurrence of *E. coli* in almonds of nonpareil variety. *Food. Tech.* 23:227-232.
14. Mirocha, C. J., and E. E. Wilson. 1961. Hull rot of almonds. *Phytopathology* 51:843-847.
15. Pons, W. A., Jr., A. F. Cucullu, and A. O. Franz. 1972. Rapid quantitative TLC method for aflatoxins in cottonseed products. *J. Assoc.*

Offic. Anal. Chemists 55:768-774.
16. Raper, K. B., D. I. Fennell. 1965. The genus *Aspergillus*. The Williams and Wilkins Co. Baltimore, 686 p.
17. Robertson, J. A., Jr., L. S. Lee, A. F. Cucullu, and L. A. Goldblatt. 1965. Assay of aflatoxin in peanuts and peanut products using acetone-hexane-water for extraction. *J. Amer. Oil Chemists' Soc.* 42:467-471.
18. Wehner, F. C., and C. J. Rabie. 1970. The micro-organisms in nuts and dried fruits. *Phytophylactica* 2:165-170.
19. Wink, W. A., and G. R. Spears. 1950. Instrumentation studies LVII. Equilibrium relative humidities above saturated salt solutions at various temperatures. TAPPI 33:96-99.
20. Wood, M. N. 1924. Almond varieties in the United States. *U.S. Dept. Agr. Bul.* 1282.

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Collapse of 'Murcott' Tangerine Trees[1]

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Additional index words. citrus, decline, fertilization, crop-strain, carbohydrate, thinning

Abstract. **'Murcott' tangerine (*Citrus* hybrid) trees often decline suddenly during fall and winter, if they are heavily loaded with fruit. First symptoms are wilt, yellowing of leaves, defoliation, and shriveling of fruit. The rapid loss of leaves and fruit, followed by dying back of branches, gives the appearance of death. However, such trees generally recover. The remaining leaves are deficient in one or more minerals such as N, P, K, or Mn. However, extra fertilizer does not prevent tree collapse. Seasonal studies showed that starch depletion and death of feeder roots accompany the decline. Root starvation, as a result of crop strain, appears to be the primary cause of rapid tree collapse.**

The 'Murcott' tangerine is a mandarin hybrid of unknown origin. It is thought (2) to be an early USDA cross between a tangerine and an orange [*Citrus reticulata* Blanco x *C. sinensis* (L.) Osbeck]. If that were so, it would be a tangor. However, it is commonly known as a tangerine in Florida, the main area in which it is grown.

'Murcott' is an extremely fruitful cultivar. Typically, the trees set so much fruit one year that they are unable to set a return crop the next. Under a heavy load of fruit, the trees decline in the fall months. Decline severity ranges from mild to drastic. In the latter case, both the leaves and fruit are shed, and the tree may appear to be dead. Such trees, however, are generally capable of recovering. The outer wood dies but new sprouts arise from the larger branches. In 1 or 2 years the tree returns to a vigorous condition and then repeats the cycle. Because of the rapidity of the decline, the condition is referred to as "collapse."

'Murcott' collapse has been attributed to a deficiency of minerals, especially N and K (6). This tentative conclusion was reached after a comparison was made of the mineral composition of various parts of healthy and collapsed trees and after some preliminary fertilizer trials. The recommended rates of N and K for 'Murcotts' were increased sharply in 1972 (4). Rates up to 450 kg/ha (400 lb./acre) for each element were suggested.

In 1968, I started several field tests to determine appropriate rates of fertilization for trees of various ages. In each experiment, supplemental amounts of N and K were added to the amounts applied by the cooperating growers.

From 1968 through 1973, collapse ranged from mild to severe in all test blocks. Rates of N and K, either separately or in combination, had little or no effect on the amount of tree collapse. Consequently, the study was broadened to include some of the physical and chemical changes that occur in the tree during the year in relation to collapse. Finally, I examined how thinning the crop of fruit affected the rate of collapse.

This report summarizes the results of these studies.

Materials and Methods

Fertilization. Five commercial 'Murcott' orchards in the ridge section of central Florida were given extra applications of NH_4NO_3 and KCl in 1968 and 1969. One of these, continued for 6 years, is used to illustrate the relation of fertilization to collapse. This was a young grove set in 1965. The trees were from nucellar budwood propagated on 'Carrizo' citrange [*C. sinensis* x *Poncirus trifoliata* (L.) Raf.].

The trees were set 350/ha and fertilized with the recommended rate of 8–2–8–3–0.5–0.25–0.1 through 1970 (4). In 1971 and thereafter, a 16–4–20 mixture was applied twice a year to all trees as a basic level. This supplied about 185 kg/ha each of N and K. Test plots received 2 appropriate supplemental applications of NH_4NO_3 and KCl by hand to make 3 levels of N and K (Table 1). Test plots, separated by buffers, consisted of 4 trees each in a 3^2 factorial plan for N and K. The 9 treatments were replicated 4 times, totaling 144 trees.

About 5-month-old leaves from nonfruiting twigs were collected each August for mineral analysis. The number of trees showing strong symptoms of collapse was counted each December or January.

Vegetative samples for starch trends and feeder root density. During 1972 and 1973, samples of leaves, twigs, scaffold root wood, and fibrous roots were collected almost monthly from 6 commercial 'Murcott' and 2 'Valencia' orchards. For twig and leaf samples, we cut a branch from each of 6 trees at each location. From these, samples of wood 1 cm diam (bark included) were composited into one sample. Thirty-six mature leaves of all ages were composited into a leaf sample.

We obtained root samples by taking 12 cores of soil from each orchard and screening out the roots. These cores were taken at the drip line of 12 trees and from all directions of exposure. The cores were 7.5 cm diam and 15.0 cm deep (3 and 6 in.). Pieces of scaffold roots between 0.5 and 1.0 cm diam

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This is a report on the current status of research involving use of certain chemicals that require registration under the Federal Environmental Pesticide Control Act (FEPCA). This report does not contain recommendations for the use of such chemicals, nor does it imply that the uses discussed have been registered. All uses of these chemicals must be registered by the appropriate State and Federal agencies before they can be recommended.