or zinc as phosphates or basic compounds ordinarily considered insoluble.

Literature Cited

1. PEECH MICHAEL. Availability of ions in light sandy soils as affected by soil reaction. Soil. Sci. **51**: 473-486. 1941.
2. JAMISON, V. C. Adsorption and fixation of copper in some sandy soils of central Florida. Soil Sci. **53**: 287-297. 1942.
3. JONES, H. W., O. E. GALL, AND R. M. BARNETTE. The reaction of zinc sulfate with the soil. Fla. Agric. Exp. Sta. Tech. Bull. 298. 1936.
4. NELLER, J. R., AND W. T. FORSEE, JR. Fertilizer experiments in an orange grove in the eastern everglades. Proc. Fla. State Hort. Soc. **54**: 1-4. 1941.

DECAY CONTROL IN FLORIDA LEMONS

J. R. WINSTON, Senior Horticulturist
and G. A. MECKSTROTH, Associate Pathologist
Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture

Although lemons have been grown in Florida on a limited commercial scale for many years, the industry has never assumed large proportions. There are good reasons for this. In addition to the problems peculiar to lemon production, several other problems present themselves after the crop is harvested.

Florida lemons mature and are usually marketed in late summer and fall. They are susceptible to the same types of decay found commonly in other citrus fruits at that season. Stem end rot is the most prevalent form of spoilage, mainly because weather conditions at harvest time are more favorable for the development of the organisms causing stem end rot, **Phomopsis citri** and **Diplodia natalensis**, than for the development of other common rot-producing fungi. These two organisms gain entrance into the fruit only through the stem parts, rarely making the invasion in less than two or three days after the fruit is harvested.

If frequent showers occur when the fruit is being harvested, stem end rot may develop quite rapidly, but during a protracted drought this rot is not likely to develop so quickly. However, regardless of moisture conditions at harvest time, stem end rot remains the principal cause of decay in Florida lemons.

Lemons at harvest time are usually too green in color to be attractive, so the common practice is to degreen them with ethylene in the same manner as oranges. Conditions for this "coloring" are also excellent for the rapid growth of Diplodia, and stem end rot caused by this fungus is likely to develop in gassed fruit unless measures are taken to prevent it. Fortunately this gassing treatment loosens the stems to such an extent that they may be removed easily, especially early in the season.

The object of this investigation was to apply or devise a control measure for stem end rot in lemons which does not greatly upset existing handling or marketing practices. The fact was recognized that lemons are likely to be held at room temperature during marketing and consumption and that

this period is likely to be longer than with many other fruits.

The experiments reported herein cover two seasons and are limited to harvesting methods and the use of antiseptics applied before or after the fruit was subjected to ethylene.

Materials and Method

The lemons used in 1937 were from young Perrine trees in Highlands County and from old Villa Franca trees in Orange County. The latter grove was again used in 1942 as a source of fruit. In the season of 1937 harvesting by pulling the fruit was compared with the more common practice of harvesting by clipping. The removal of the stem buttons immediately after the gassing treatment and also the effectiveness of 8% borax applications as decay preventive measures were tested, but none of the fruit was treated with wax or other wilt retarding materials. In 1942 the same tests were repeated and expanded to include applications of antiseptics in water or in wax emulsion, or simply wax emulsion applied after the fruit had been subjected to the usual degreening treatment.

No unusual care was exercised in harvesting or handling the fruit. The lemons were brought to the laboratory at Orlando the day they were picked and sorted to remove bruised, clipper-cut, and badly torn or "plugged" fruits.

Borax applied before gassing consisted of an 8% solution in water at 110° F. for two minutes. The antiseptic was allowed to dry and remain on the fruit until after the gassing period.

Fruit was left in the ethylene room only long enough to degreen, never more than 64 hours. The room was operated at 82°F., 92% relative humidity. The ethylene never exceeded a concentration of 1-50,000.

At the end of the gassing period all lots of fruit were washed and some were given one of the following post-gassing treatment: (1) 1.2% sodium-ortho-phenyl-phenol in water followed immediately by thorough rinsing; (2) 2% borax in a diluted wax emulsion; (3) wax emulson (19% solids, mostly paraffin), diluted 1-10; (4) wax emulsion (19% solids, mostly paraffin), applied 24 hours after the gassing period; (5) 2% sodium-ortho-phenyl-phenol in a diluted wax emulsion applied 24 hours after gassing. All applications were made at 100° F. for two minutes, and the fruit receiving the various wax emulsions was not rinsed afterwards. All lots were passed over drying brushes to remove excess moisture.

The various collections of lemons were then stored in a holding room for thirty days. This room was maintained at a fairly constant temperature, near the average for the season; in late summer it was held at about 80°, but it dropped gradually to 75° in mid-fall. The fruit was inspected twice each week, and all decaying or badly blemished individuals were recorded and discarded.

The data obtained from holding the Perrine and Villa Franca lemons are treated separately because of difference in age of the trees, their location, and varietal characteristics.

Results

The spoilage data obtained in 1937 from holding tests with two lots of Perrine lemons of 50 fruits each and three lots of Villa Franca lemons of approximately 50 fruits each are presented in table 1.

Perrine Lemons

Perrine lemons harvested by pulling developed much less decay than those harvested by clipping whether non-gassed (comparison A), or gassed (comparison B). The gassing treatment increased decay in both clipped and pulled fruit, a fact which has been known so long that it hardly warrants comment (comparisons A and B).

8% borax applied before the gassing treatment reduced decay in clipped fruit but failed to reduce it in pulled fruit (comparisons C and B).

Pulled, gassed fruit (not treated with borax) (B) held up better than clipped, borax-treated, gassed fruit (C) and about as well as clipped, borax-treated fruit dis-

TABLE 1. Decay development in Florida lemons as influenced by harvesting methods and packing house treatments.
Percent decay accumulatively—1937—Perrine and Villa Franca Lemons

Method of Harvesting and Treatment	Comparison	No. Lots	No. Fruit	Percent decay—cumulative							
				Days after picking							
				6	9	13	16	20	23	27	30
Perrine Lemons											
Clipped, no treatment	A	2	100	0	8.0	18.0	24.0	31.0	38.0	43.0	44.0
Pulled, no treatment	A	2	100	1.0	2.0	3.0	7.0	9.0	13.0	17.0	20.0
Clipped, ethylene	B	2	100	8.0	35.0	49.0	53.0	62.0	66.0	67.0	68.0
Pulled, ethylene	B	2	100	2.0	3.0	11.0	16.0	19.0	23.0	25.0	27.0
Clipped, borax, ethylene	C	2	100	2.0	8.0	18.0	24.0	26.0	29.0	29.0	32.0
Pulled, borax, ethylene	C	2	100	0	4.0	10.0	13.0	17.0	21.0	25.0	25.0
Clipped, ethylene, disbutton	D	2	100	1.0	5.0	11.0	14.0	15.0	15.0	17.0	17.0
Clipped, borax, ethylene disbutton	D	2	100	0	3.0	8.0	14.0	19.0	23.0	26.0	28.0
Clipped	E	All	300	3.3	17.0	28.3	33.7	39.7	44.3	46.3	48.0
Pulled	E	All	300	1.0	3.0	8.0	12.0	15.0	19.0	22.3	26.0
Villa Franca Lemons											
Clipped, no treatment	A	3	160	1.2	3.7	8.7	12.5	18.7	23.7	29.4	35.0
Pulled, no treatment	A	3	134	.7	5.2	9.7	12.7	20.9	28.3	34.3	43.3
Clipped, ethylene	B	3	160	3.7	41.9	60.0	65.6	71.9	80.6	85.0	87.5
Pulled, ethylene	B	3	150	.7	14.7	28.0	32.7	39.3	48.7	57.3	62.0
Clipped, borax, ethylene	C	3	160	3.7	16.9	26.9	35.6	46.2	51.2	56.9	61.2
Pulled, borax, ethylene	C	3	150	2.0	23.3	35.3	38.7	42.7	48.7	53.3	58.7
Clipped, ethylene, disbutton	D	3	160	3.7	11.2	15.6	16.9	20.0	21.3	21.3	27.5
Clipped, borax, ethylene, disbutton	D	3	160	1.9	11.9	15.6	22.5	28.1	30.6	35.0	39.4
Clipped	E	All	480	2.9	17.1	25.4	30.6	37.0	41.5	45.5	50.1
Pulled	E	All	434	1.0	12.5	22.9	27.4	33.9	41.4	48.1	54.8

buttoned after gassing (D).

Fruit disbuttoned after the gassing treatment gave the most effective decay control in the clipped lots. Borax applied to such fruit before gassing had but little effect on subsequent decay (comparison D).

When the fruit was grouped by harvesting methods, pulled fruit decayed much less rapidly than clipped fruit (E).

Villa Franca Lemons

Pulling did not reduce decay in non-gassed fruit of Villa Franca (comparison A). Gassed lemons harvested by pulling decayed much less rapidly than those clipped from the trees (comparison B). Again the ethylene treatment stimulated decay in both clipped and pulled fruit, but the increase was greater in the clipped lots (comparisons A and B). Borax greatly reduced decay in clipped fruit subjected to ethylene but did not reduce decay in pulled fruit (comparisons B and C). Disbuttoning of gassed fruit gave the most effective decay control. Borax applied before gassing did not further reduce decay in disbuttoned fruit (comparison D).

When the fruit was grouped by harvesting method, that harvested by pulling decayed slightly less than clipped fruit (comparison E).

During the fall of 1942 the investigation was resumed, being limited, however, to Villa Franca lemons but expanded to include the use of sodium-ortho-phenyl in water and sodium-ortho-phenyl-phenol as well as borax added to the water phase of the emulsion for decay control, and wax emulsion for shrinkage control. Results are presented in Table 2.

In both non-gassed (A) and gassed (B), clipped fruit decayed more rapidly than pulled fruit, and again ethylene stimulated decay in both clipped and pulled fruit (comparisons A and B).

8% borax solution applied immediately after harvest reduced decay in gassed fruit (comparisons C and B), but the reduction was greater in the clipped than in the pulled.

Disbuttoning after the gassing period gave the most effective control of decay. Borax application given before the gassing treatment did not further reduce decay in fruit disbuttoned after gassing (treatment D).

2% borax applied in wax emulsion after gassing failed to reduce decay (comparisons E and H).

2% phenate (sodium-ortho-phenyl-phenol) in wax emulsion applied to clipped fruit immediately after gassing was about as effective during the first two weeks as borax applied before gassing. During the latter half of the holding period, borax afforded the greater protection, a commonly accepted fact. On pulled fruit the phenate was more effective than borax for about three weeks (comparisons C and G).

Delaying the application for one day, using the original solutions of phenate in emulsion, did not reduce its efficiency in controlling decay (comparison G and J).

1.2% phenate in water applied after gassing was considerably less effective in controlling decay in clipped fruit than borax applied before gassing, but on pulled fruit was somewhat more effective (comparisons C and F).

Wax emulsion applied either immediately after the gassing period or a day later had but little effect on decay in clipped fruit. However, the former may have stimulated decay slightly in pulled fruit during the first three weeks (comparisons H and I).

In eight out of nine comparisons decay developed more rapidly in the clipped fruit than in the pulled. In the one exception there was little difference in the rate of decay throughout the holding period.

When consolidated by methods of harvesting, pulled fruit again held up better than clipped (comparison K).

During the progress of this investigation cultures were made from stem-end rot infected fruits as shown in table 3. Cultures from non-gassed fruit showed that approximately 90% of this decay was caused by **Phomopsis citri,** the melanose fungus.

TABLE 2. Decay development in Florida lemons as influenced by harvesting methods and packing house treatments.

Percent decay accumulatively—1942—Villa Franca Lemons

Method of Harvesting and Treatment	Comparison	No. Lots	No. Fruit	Percent decay—cumulative							
				Days after picking							
				6	9	13	16	20	23	27	30
Clipped, no treatment	A	6	346	0	.6	4.3	8.7	15.3	18.5	22.3	25.7
Pulled, no treatment	A	6	312	0	.3	1.0	2.2	4.2	6.9	8.3	9.9
Clipped, ethylene	B	6	345	.3	4.9	16.2	24.3	32.5	35.9	39.7	43.5
Pulled, ethylene	B	6	313	.3	5.4	11.8	14.7	17.6	20.8	25.2	27.2
Clipped, borax, ethylene	C	6	346	0	1.2	5.8	9.2	13.0	16.2	17.9	19.7
Pulled, borax, ethylene	C	6	318	.6	4.1	6.3	9.1	13.8	17.7	19.6	21.5
Clipped, ethylene, disbutton	D	6	346	0	.9	1.2	3.2	3.8	4.6	5.2	5.5
Clipped, borax, ethylene, disbutton	D	6	346	.6	2.0	3.8	4.6	6.4	8.4	10.4	11.6
Clipped, ethylene, borax in emulsion	E	5	271	.4	7.7	25.1	34.7	44.3	46.9	50.2	54.2
Pulled, ethylene, borax in emulsion	E	5	261	.8	7.3	13.8	17.6	21.1	24.1	27.6	30.7
Clipped, ethylene, phenate* in water	F	6	351	0	2.6	14.0	22.2	33.0	35.9	41.6	46.2
Pulled, ethylene, phenate in water	F	6	324	1.2	2.2	4.9	6.2	9.3	10.8	14.5	17.0
Clipped, ethylene, phenate in emulsion	G	6	343	0	.3	7.3	18.4	32.7	40.2	47.2	51.9
Pulled, ethylene, phenate in emulsion	G	6	314	1.0	1.3	3.2	5.7	8.6	14.0	18.5	21.3
Clipped, ethylene, wax emulsion	H	6	346	.3	5.8	18.8	26.3	32.9	38.2	45.1	47.4
Pulled, ethylene, wax emulsion	H	6	315	.6	12.7	18.4	22.2	25.4	26.7	29.8	33.0
Clipped, ethylene, emulsion, delayed	I	4	225	0	3.1	13.3	20.0	30.7	33.3	37.3	40.0
Pulled, ethylene, emulsion, delayed	I	4	222	1.4	3.6	10.4	14.0	19.4	23.4	24.8	27.5
Clipped, phenate in emulsion, delayed	J	4	222	.5	1.4	4.5	9.0	20.7	31.1	40.1	46.4
Pulled, phenate in emulsion, delayed	J	4	217	.9	2.3	4.1	5.1	7.8	8.8	10.6	12.0
Clipped	K	All	3137	.1	2.8	11.7	18.6	27.7	32.4	37.2	40.8
Pulled	K	All	2923	.6	3.9	7.4	9.4	12.9	15.6	18.5	21.0

* Sodium-ortho-phenyl-phenol. 1.2% in water; 2% in diluted wax emulsion.

Ethylene increased stem-end rot and greatly increased the proportion caused by **Diplodia natalensis.**

Borax suppressed the percentage of stem-end rot in gassed fruit to approximately that in non-gassed fruit, and the proportion of Diplodia rot was much less than in the non-borated lot, but probably greater than in non-gassed fruit.

Sodium-ortho-phenyl-phenol afforded its principal protection against stem-end rot during the first two weeks after treatment.

TABLE 3. Effect of packing house treatments on the development of the fungi causing stem end rot in leemons harvested by clipping. 1942.

Treatment	Number of fruit		Percent	
	In Test	With Stem End Rot	Phomopsis	Diplodia
No treatment:	232			
1st 13 days		8	87.5	12.5
Next 14 days		45	91.1	8.9
Total in 30 days		58	93.1	6.9
Ethylene:	232			
1st 13 days		27	22.2	77.8
Next 14 days		53	56.6	43.4
Total in 30 days		88	43.2	56.8
Borax before ethylene	232			
1st 13 days		10	60.0	40.0
Next 14 days		29	93.1	6.9
Total in 30 days		44	86.4	13.6
Phenate* in water after ethylene:	234			
1st 13 days		20	40.0	60.0
Next 14 days		72	68.1	31.9
Total in 30 days		103	63.1	36.9
Phenate in wax emulsion: (after eth.)	230			
1st 13 days		16	37.5	62.5
Next 14 days		88	72.7	27.3
Total in 30 days		118	66.1	33.9

* Sodium-Ortho-phenyl-phenol. I.2% in water; 2% in diluted wax emulsion.

Throughout the holding period there was proportionately less Phomopsis rot in these lots than in those treated with borax.

Discussion

The difference in rate of decay in fruit from the same trees during two seasons is worthy of comment. In 1937 the rate was nearly normal, whereas, in 1942 it was much lower than usual, as was also true with oranges and grapefruit. Weather conditions at or immediately before harvest time are known to have a marked influence on the keeping quality of citrus fruits. The fall of 1942 was exceedingly dry and not conducive to the development of rots.

The effectiveness of pulling fruit as a means of checking decay was quite consistent and the failure of borax to further reduce decay in pulled fruit has also been observed repeatedly in grapefruit.

The development of stem end rot in pulled grapefruit is very much in proportion to the amount of stem parts left adhering to the fruit. If the stem was broken at the base of the calyx, little if any reduction in stem-end rot was recorded. When half or more of the calyx was removed, a substantial reduction in rot was noted; when all of the calyx was removed, leaving only the petal and stamen base, a further reduction was noted; when the entire button was removed without tearing the rind tissue, the maximum decay reduction resulted. Thus complete removal of the stem parts is es-

sential for maximum decay control by this method, which probably applies to lemons as well as to grapefruit. With pulled lemons usually the entire button was removed, but in a small percentage of cases the rind was torn or "plugged" during harvesting, but no more frequently than clipper cuts occurred.

The efficiency of disbuttoning after gassing as a means of checking decay is strong evidence that the stem or stem parts is the principal avenue of entrance of the stem end rot fungi into the flesh of the lemons. This is also true with grapefruit.

The data presented in tables 1 and 2 show abundant evidence that decay can be reduced through the use of antiseptics. Of the several antiseptics tested, borax is the safest and most effective over a long period, but to obtain maximum results with oranges and grapefruit it must be applied before the fruit is gassed, and be left on during the gassing period. The same principle probably applies with lemons, since the same fungi must be dealt with. There are other compounds, phenol derivatives, such as sodium-ortho-phenyl-phenol (Dowicide A), which for a week or two are about as effective as borax, and they can be applied either immediately after gassing or even a day later, in water or in most wax emulsions, with but little added effort or expense. These features are distinctly advantageous. To be effective and safe, both the temperature and the concentration of the antiseptic bath must be held within rather narrow limits, which, however, are not difficult to maintain.

Wax emulsion proved very effective in preserving a fresh, attractive appearance of the fruit without affecting flavor. 1/. Unless special protective measures are taken, the marketing and consuming period must be short or excessive spoilage is likely to be encountered. The rate of decay varies from year to year and from grove to grove.

Cultures made from fruits which had developed stem end rot showed that Phomopsis was the principal cause of rot in non-gassed fruit. After gassing the rapidly growing Diplodia increased considerably making its greatest increase in the fruit not treated with an antiseptic and least in that treated with borax. The increase in Diplodia could hardly be attributed to temperature of the coloring room because in the first and second pickings the heating equipment was not in use, and the gassing room was no warmer than the holding room. Dr. Charles Brooks pointed out at the meeting of this Society two years ago that ethylene activates the spores of the stem end rot fungi, particularly Diplodia.

Summary

Florida lemons ripen during late summer and fall when the weather is still warm and favorable for rapid decay development, especially stem end rot. The ethylene treatment, commonly applied to improve the color of citrus fruits, also renders lemons especially susceptible to rapid attack from the two stem end rot fungi.

Spoilage developed less rapidly in pulled than in clipped lemons. Such antiseptics as an 8% borax solution in water applied soon after the fruit is harvested, or sodium-ortho-phenyl-phenol (1.2% in water and rinsed off immediately, or as much as 2% in wax emulsion after gassing) were effective in checking decay and caused no rind injury.

Wax emulsion retarded withering and aging, thereby prolonging the period that the fruit remained in a fresh, attractive condition.

Phomopsis citri caused most of the stem end rot in non-gassed lemons. Ethylene greatly stimulated the development of the rapidly growing **Diplodia natalensis** and borax was more effective than phenate in controlling it.

1/. This point is especially important since fruit exposed to the hot, dry fall air is likely to wither and become unattractive unless quickly consumed. The greatest amount of wilting was noted in the non-waxed lots, the least in those treated with plain wax emulsion.