Table 1. Percentage decay in 'Bearss' lemons following curing without and with ethephon during simulated marketing after 3 days simulated transit plus 2 days warehouse (WH), 4 wk retail (R), and 2 wk home fruit bowl (FB). (Avg of 3 replications for each of 3 harvests).[z]

Treatment	Simulated marketing stage		
	WH	R	FB
Check	1.2 a	6.8 a	13.1 a
1000 ppm ethephon	1.4 a	9.3 ab	16.9 b
2000 ppm ethephon	2.4 a	10.6 b	18.7 b

[z]Values in each column followed by like letters are not significantly different according to Duncan's multiple range test at the 0.5% level.

resulted in more decay after an additional 2 wks in "home fruit bowl" conditions.

Discussion

Color differences among a wide range of ethephon treatment levels were negligible for lemons harvested at monthly intervals beginning in mid-August. The harvest date for the work reported by Jahn (5) was mid-August three years earlier, and results were similar for similar temperatures and ethephon rates. Repeated tests are needed to determine optimum ethephon levels for Florida lemons when harvest begins in mid-July. The curing time of Florida lemons was reduced appreciably with ethephon, which is of commercial interest, due to the need to market lemons early in the summer.

Decay levels were higher with high rates of ethephon and long simulated marketing periods. Rates of 1/30 that used for decay evaluation proved to be adequate for color development on the October harvest. Decay results, therefore, should be considered with caution as lower ethephon rates (for which decay was not evaluated) may be adequate throughout the season.

Literature Cited

1. Brown, G. E., and W. Grierson. 1966. Stem-end rot fungi in Florida fresh lemons. *Plant Dis. Rept.* 50(1):860-861.
2. Fuchs, Y., and A. Cohen. 1969. Degreening of citrus fruit with Ethrel (AmChem 66-329). *J. Amer. Soc. Hort. Sci.* 94(6):617-618.
3. Grierson, W. 1968. Harvesting and marketing preparation techniques for Florida lemons. *Proc. Amer. Soc. Hort. Sci.* 92:797-806.
4. ———— and S. V. Ting. 1960. Florida lemons for fresh and cannery use: Variety selection and degreening methods. *Proc. Fla. State Hort. Soc.* 73:284-289.
5. Jahn, O. L. 1973. Degreening citrus fruit with post-harvest applications of (2-chloroethyl) phosphonic acid (ethephon). *J. Amer. Soc. Hort. Sci.* 98(3):230-233.
6. Oberbacher, M. F., and W. Grierson. 1960. Handling methods for fresh lemons: Low temperature curing studies with the Sicilian variety. *Proc. Fla. State Hort. Soc.* 73:236-240.
7. Soule, J., W. Grierson, and J. G. Blair. 1967. Quality tests for citrus fruits. *Univ. of Fla. Ext. Circ.* 315.
8. Tucker, D. P. H. and W. F. Wardowski. 1973. Lemon production and utilization in Florida. *Fla. Ext. Bull.* 184.
9. Vakis, N. I. 1973. Degreening citrus fruits with ethephon. Republic of Cyprus. *Prog. Rept.* No. 20.

DEGREENING OF FLORIDA LEMONS[1]

OTTO L. JAHN

Agricultural Research Service,
U.S. Department of Agriculture
Orlando

Abstract. **'Bearss' lemons (Citrus limon Burm. f.) were effectively degreened by ethylene or ethephon at 60°F (16°C). The time required to reach an acceptable color was reduced by up to 33% with concn of 5 ppm ethylene or 500 to 1,000 ppm ethephon. Higher temps increased the rate of degreening, but also increased decay, especially with ethylene at 80°F (27°C). Stem-end decay was minimal at 60° with or without a fungicide. The combination of ethephon with thiabendazole (TBZ) did not affect the degreening rate. Delays in applying ethephon delayed the start of degreening but did not increase the degreening time. The response to ethephon was not appreciably affected by washing the fruit before treatment or by applying the chemical in split applications at harvest and before storage.**

Interest in lemon production for the fresh market in Florida is increasing. One major obstacle is getting lemons satisfactorily colored for market. Lemons are susceptible to decay with conventional ethylene degreening at 85°F (29°C) (4) and the use of ethylene is not recommended (5). Lemons are now held at 60°F (16°C) until they are satis-

[1]Acknowledgment is given the Foods Division, Coca-Cola Company, for providing the lemons, and to Amchem Products, Inc. for the ethephon used in these studies.

factorily colored, which requires 3 to 6 weeks for fruit harvested in July or August. Since these extended degreening periods occur during the peak summer marketing period, such delays are costly.

Previous studies showed that degreening lemons at 60°F could be accelerated with 500 to 1,000 ppm ethephon, and that ethylene could also be used at this temp (1). For this reason, work was continued to develop practical methods of degreening lemons using ethylene and ethephon (which serves as a carrier of ethylene). (Some data from the ethylene studies are also being published elsewhere (2).)

Material and Methods

'Bearss' lemons (and small samples of other varieties) were obtained either directly from the grove in Martin County, or from the packinghouse after transport from the grove. Effects of ethylene concn and temp were studied in 2 tests initiated on July 24 and September 12, 1972. Samples of 20 fruits each were treated with levels of 0, 1, 5, 10, 20, or 50 ppm ethylene in closed chambers as described previously (1). Lemons were degreened for 2 or 4 days at 80°, and 4 or 6 days at 60°F. Fruit at 80°was transferred to 70° on completion of degreening.

Effects of ethephon concn and temp were studied in 4 tests initiated on July 12, 1972, July 18, August 29, and September 20, 1973. Samples of 20 fruits were treated with concn of 0, 500, 1,000, and 2,000 ppm ethephon in a flood application and held at 60, 70, and in 1 test, 80°F. A number of other variables, including delayed treatment, retreatment, washing, and combination of ethephon with TBZ were also evaluated. In all tests with ethephon, Triton X100 (.1%) was used as a wetting agent.

Changes in fruit color during degreening were followed with a light-transmittance difference meter (1, 3). Measurements, recorded as △OD 695-740 nm, indicate the relative levels of chlorophyll in the fruit. For comparison, levels of .6 to .7 △OD indicate a medium-dark green color, and .3 △OD is an acceptable pale-yellow color. Records were kept of the incidence of decay during degreening. Losses were mostly due to stem-end decays, with few from *Penicillium*.

Results and Discussion

Ethylene induced degreening in lemons at 60°F and reduced the time needed to reach an acceptable color (Fig. 1). (The untreated fruit would have required at least another 10 days to be fully colored.) The lemons continued to degreen rapidly after removal from ethylene but the rate eventually declined until it was comparable to that of untreated fruit. With 4 days treatment, 5 ppm ethylene was sufficient to give a maximum rate of degreening, but the fruit did not attain an acceptable color. With 6 days treatment, maximum responses were obtained with 10 ppm ethylene, and with continued degreening, some samples reached a minimum acceptable color in 10 to 12 days. Higher ethylene levels gave responses similar to 10 ppm as was also found for 'Hamlin' oranges (3). These were dark-green fruit, typical of early harvests,

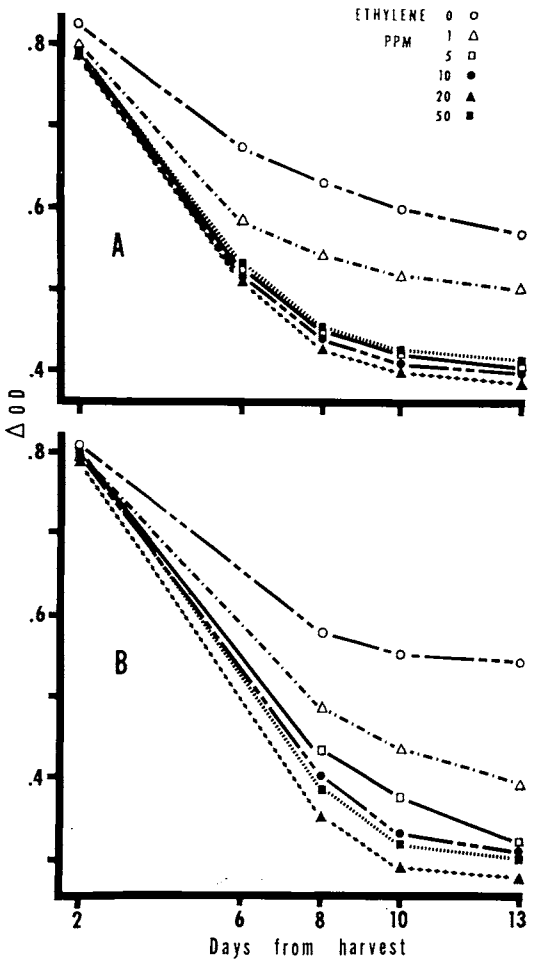

Fig. 1. Chlorophyll levels (△OD) in 'Bearss' lemons with: (A) 4, or (B) 6 days degreening at 60°F in atmospheres of 0 to 50 ppm ethylene. Average of single 20-fruit samples (harvested July 24, 1972). Color is acceptable at .3 △OD or lower.

and would have benefited from an additional day of ethylene treatment or several additional days at 60° to complete the color development. In the second test, ethylene also induced degreening, and reduced the degreening time by approximately 30% (2). Fruit degreened at 80°F (data not shown) showed more rapid changes but ethylene response patterns were similar to those at 60°.

Excessive stem-end decay developed in many samples at 80°, especially those treated with higher ethylene levels for 4 days. At 60°F, decay losses were erratic with a trend to greater frequency with 20 and 50 ppm ethylene. No fungicide was used in this test. Experience suggests that decay would not be a serious problem at 60° if ethylene were limited to a level of 5 ppm. Also, washing and treating lemons with a fungicide before degreening has greatly reduced decay (4).

Ethephon at 500 or 1,000 ppm was adequate to induce maximum degreening in 'Bearss' lemons at 60°F (Fig. 2). Application of 500 ppm reduced the degreening time by 6 days, or more than 25%, compared to untreated fruit. (In other tests, the degreening time has been reduced by 15 to 33%.) At 70°, lemons treated with 500 ppm ethephon reached an acceptable color (.3 △OD) slightly later than at 60°. Higher concn gave a somewhat more rapid response at 70° than at 60°, while untreated lemons often did not reach an acceptable

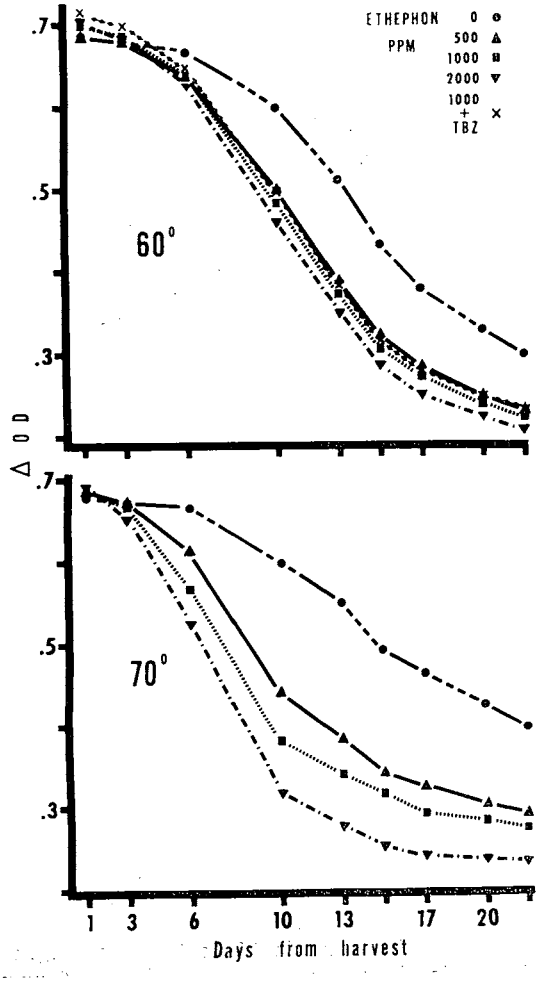

Fig. 2. Chlorophyll levels (△OD) in 'Bearss' lemons following applications of 0 to 2,000 ppm ethephon during storage at 60° or 70°F. Average of single 20-fruit samples (harvested July 18, 1973). Color is acceptable at .3 △OD or lower.

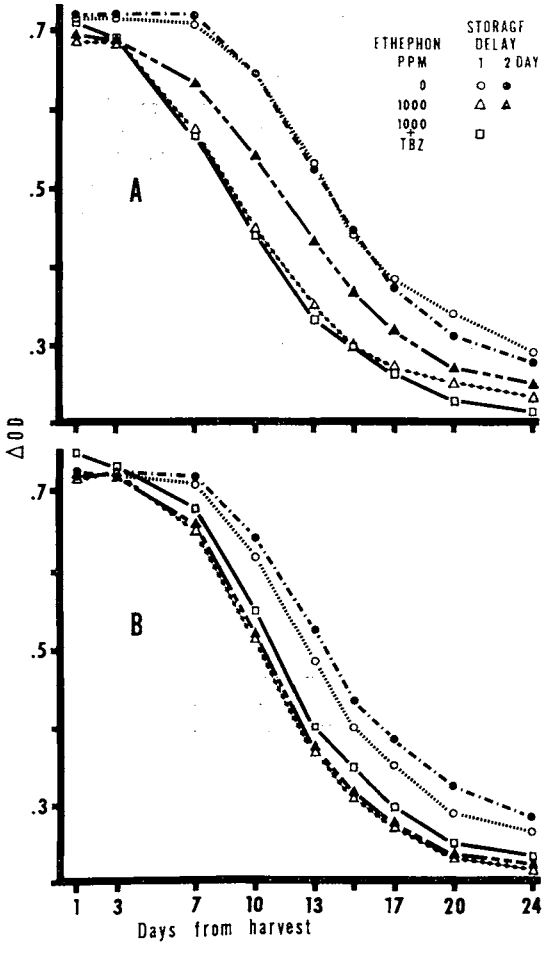

Fig. 3. Chlorophyll levels (△OD) in 'Bearss' lemons treated with ethephon. (A) Before 1- or 2-day delay preceding storage, and (B) after 1- or 2-day delay and preceding storage at 60°F. Average of single 20-fruit samples (harvested August 29, 1973). Color is acceptable at a .3 △OD or lower.

color at 70°. Normally, higher temp increase the degreening rate of citrus fruits. However, increased temp also increases the rate of breakdown of ethephon and the release of ethylene and this must be balanced against the degreening rate in the fruit. This balance may provide more rapid degreening at 65° than has been observed at either 60° or 70°F.

Lemons treated with ethephon in the field after harvest were compared with applications at the laboratory 1 or 2 days later. Field-treated fruit were held at ambient temp (80° to 85°F) for this period to simulate transit conditions to the packinghouse. Lemons treated in the field and held 1 day (Fig. 3A) initiated degreening earlier than those treated after 1 or 2 days' delay (Fig. 3B), but there was little or no difference in the time required to reach an acceptable color (.3 △OD). Degreening was retarded in fruit held 2 days compared to fruit held 1 day at ambient temp after treatment with ethephon (Fig. 3A), indicating that much of the chemical broke down during this high temp period.

In the studies presented (Figs. 2 and 3), TBZ applied with ethephon did not affect the degreening response. These results should be treated cautiously as these chemicals are of marginal compatibility. TBZ is formulated with a high pH and ethephon is unstable at high pH. Preliminary tests indicate that consistent degreening and decay control may be possible if the mixture is kept below pH 4.

In other treatments, comparisons indicated little or no benefit from pretreating lemons with ethephon before degreening with ethylene (data not shown). Washing fruit prior to applying ethephon also did not appreciably alter the degreening response. Although a wetting agent was used in these tests, data from other samples indicate that this probably is not necessary for a response to ethephon. Split applications of 500 or 1,000 ppm ethephon in the field followed by washing and retreatment 1 day later increased the degreening rate significantly, but the increase is too small to be of practical value.

Untreated 'Harvey', 'Avon', 'Italian', and 'Villafrance' lemons were compared with 'Bearss' in the 1973 tests. 'Harvey' and 'Avon' lemons colored 2 to 5 days earlier than the other varieties, suggesting that they may be easier to degreen than 'Bearss'.

Ethephon, like ethylene, increased postharvest decay losses (1). Decay was not serious in lemons degreened at 60°F and was controlled where treatments included TBZ. The use of ethephon does not require restricted ventilation for effectiveness. However, its use in tight, refrigerated rooms may result in the accumulation of ethylene. As ethylene levels build up, there will be less benefit from ethephon applications and such a double treatment for degreening may induce excessive decay.

Literature Cited

1. Jahn, O. L. 1973. Degreening citrus fruits with postharvest applications of (2-chloroethyl) phosphonic acid (ethephon). *J. Amer. Soc. Hort. Sci.* 98:230-233.
2. ————, ————. Ethylene concentrations and temperatures for degreening Florida citrus fruits. Proc. Int. Citrus Congress, Murcia, Spain. 1973 (in press).
3. ————, W. G. Chace, and R. H. Cubbedge. 1973. Degreening responses of Hamlin oranges in relation to temperature, ethylene concentration and fruit maturity. *J. Amer. Soc. Hort. Sci.* 98:177-181.
4. Smoot, J. J., and C. F. Melvin. 1972. Decay of degreened citrus fruit as affected by time of washing and TBZ application. *Fla. State Hort. Soc. Proc.* 85:235-238.
5. Tucker, D. P. H., and W. F. Wardowski. 1973. Lemon production and utilization in Florida. *Fla. Agr. Expt. Ser. Bull.* 184.