of the sprout inhibitor MH (Table 3). The RT and PQ treatments were applied 4 and 6 days after MH, respectively. Apparently this did not allow enough time for MH transport.

Table 3. Interations of maleic hydrazide with rolling of the tops and paraquat on the incidence of root sprouting during 3 months storage.

Maleic hydrazide	Rolling of tops		Paraquat	
	without	with	without	with
without MH	66[z]	56	54[z]	68
with MH	25	46	27	44

[z]Means for interaction significantly different by the F test, 5% level.

Growing onions in Florida will remain risky because of the high probability of adverse weather conditions at harvest. The cultivar 'Texas Grano 1030Y' may offer some advantages because of its desirable storage characteristics. A preharvest treatment with MH may enhance the storability of Florida grown onions and provide for an extended marketing season. Rolling of the tops aided in field drying of the onions in our test. It is likely that a combination of MH and RT would be most beneficial to those wishing to store Florida onions. The timing of these treatment needs further investigation to allow for MH translocation prior to rolling the tops.

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THE EFFECTS OF AN IMAZALIL-IMPREGNATED FILM WITH CHLORINE AND IMAZALIL TO CONTROL DECAY OF BELL PEPPERS

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Abstract. **Bell peppers (**Capsicum annuum **L.) were treated with a chlorine and/or imazalil dip; one-half was individually wrapped in an imazalil-impregnated heat-shrinkable plastic film and one-half remained unwrapped. They were held in storage and evaluated for incidence of decay development after 1, 2, and 3 week at 7.2°C and after 5 additional days at 15.6°C. Bacterial soft rot (BSR) was the most prevalent decay identified but fungal decay caused by** Alternaria **sp. and** Botrytis **sp. developed to a lesser extent following 3-week storage. No treatment effectively controlled the development of BSR. The imazalil film alone and imazalil dip (500 ppm) alone significantly reduced the incidence of fungal rot but film wrapping increased the incidence of BSR compared to nonwrapping after 3 week at 7.2° + 5 days at 15.6°C. The effect of the imazalil film and imazalil dip in**

combination was more effective in reducing fungal decay than each alone. Color development was slowed after 3 week at 7.2° + 5 days at 15.6°C and pod softening was consistently retarded in wrapped treatments.

The major pathogenic organisms that cause rot to Florida-produced bell peppers are bacterial soft rot, *Erwinia carotovora* (L. R. Jones) Holland, alternaria rot, *Alternaria alternata* (Fr.) Keissler, and grey mold rot, *Botrytis cinerea* Pers. ex Fr. Marketing losses due to these diseases during storage, transport and at terminal markets are well documented (4, 10). Due to the lack of an effective control against these diseases, market losses prohibit Florida shippers from successfully competing in distant markets requiring a 2-3 week delivery time.

Pepper pod softening, caused by moisture loss, is the principal physiological deterioration problem occurring during relatively long storage and marketing periods. Moisture loss ca. 7% of total pod weight causes pods to be very flaccid and to be rejected by consumers (1, 13).

Many investigations have been conducted over the years to seek effective treatments to control postharvest decay and extend the shelf life of bell peppers, but these results have produced only partial control (6, 7, 8, 9, 14, 15).

More recently, investigators in different countries have studied the effect of wrapping pepper pods in various plastic films as a means to control decay and lengthen shelf life. A brief review reveals that: 1) Bussel and Kinigsberger (3) found film wrapping reduced weight loss compared to nonwrapping; a polyethylene film retarded color development compared to other films tested; O_2 and CO_2 concentrations within wraps were related to film permeability and storage temperature; 2) Hughes et al. (5) found no difference in pepper condition among different films tested, but found wrapping to be significantly beneficial in prolonging shelf life compared with nonwrapping, and found wrapping did not cause a serious decay problem; 3) Miller and Risse (11) found that wrapping significantly reduced weight loss and pod softening, and slowed surface color development compared with nonwrapping, and although there were no significant differences in decay development between wrapping and nonwrapping, wrapping tended to increase the incidence of decay; 4) Ben-Yehoshua et al. (2), working with Israeli and Florida peppers, reported that wrapping peppers in a high-density polyethylene film reduced weight loss and pod softening, and that pulp tissue from wrapped pods had consistently less free amino acid leakage and higher water potential than those stored nonwrapped; and 5) Miller et al. (12), combining dips of chlorine (Cl) and imazalil (IM) with film wrapping found that decay did not increase during 2-week storage at 7.2°C, but significantly increased during 3-week storage; Cl reduced decay during 2-week storage but was not effective during 3-week storage; and the Cl effect was independent of wrapping. Following 2-week storage at 7.2°C + 7 days at 15.6°C, IM was effective for reducing total decay. The IM effect was dependent on wrapping but not on the presence of Cl. IM also decreased decay after 3 weeks at 7.2°C, + 3 days at 15.6°C, but the IM effect was not dependent on wrapping. In addition, amount of weight loss was reduced and surface color development retarded compared with nonwrapping.

Consideration of these film-wrapping investigations leads to the following observations: 1) film wrapping has a significant effect in extending shelf life and maintaining the quality of bell peppers when disease is not a serious problem during postharvest storage; 2) film wrapping studies reporting decay data usually combined all decay in a single decay category without identifying the incidence of decay by organism. Generally, the incidence of decay is higher when bell peppers are wrapped compared to nonwrapping and held in storage; and 3) Cl and IM have some effect on decay reduction.

No information is available on the effects of wrapping peppers in film impregnated with a fungicide. Therefore, the objectives of this study were: 1) to evaluate the effect of controlling decay when wrapping peppers with an imazalil-impregnated plastic film (IMFL) in combination with Cl and IM together and alone during 1-, 2-, and 3-week storage; and 2) to determine the effect of wrapping peppers with IMFL on pod firmness and color development during storage.

Materials and Methods

For 3 separate tests, peppers (cv. 'Cal Wonder') were obtained from a Palm Beach County grower at approximately 3-week intervals during the 1984 production season. All peppers were subjected to similar fertilizer and irrigation practices and were from the first field picking. For each test, all pods were from the same field lot. Pods ranged from 70 to 90 mm in diameter and were selected directly from the packing line immediately following the spray wash operation. Wash water was at ambient temperature (constantly replenished) but without a bactericide or fungicide. From the packing line, pods were placed into 1-bu fiberboard shipping containers and returned by auto to the Orlando Laboratory.

Peppers were selected free of physical damage, and their stems were uniformly cut off close to the calyx with small pruning shears. Peppers were randomized into lots of 120 pods each. Following the application of Cl and/or IM, one-half (60 pods) for each treatment lot was wrapped in IMFL and one-half was left nonwrapped. The treatments were:

Nonwrapped	Wrapped in IMFL
1. Control (water dip)	2. Control (water dip)
3. Chlorine (1000 ppm)	4. Chlorine (1000 ppm)
5. Imazalil (500 ppm)	6. Imazalil (500 ppm)
7. Chlorine (1000 ppm) + imazalil (500 ppm)	8. Chlorine (1000 ppm) + imazalil (500 ppm)

The Cl solution was prepared by adding household bleach (5.125% sodium hypochlorite) to 40 liters of tapwater and adjusting to 1000 ppm with the aid of a color comparator. The pH was adjusted to 7.5. The IM solution was prepared by adding 25 ml of 80% w/v stock IM to 40 liters of tapwater. Pods were placed into a mesh bag, submerged in solution for 30 sec, and then placed on kraft paper until dry. A low-density polyethylene, heat-shrinkable film, impregnated with 2000 ppm IM during extrusion, nominal thickness of 0.015 mm, was used for wrapped treatments. The IMFL was applied to each pod using a hot wire Weldomatic® sealer (Model 6001) and a Weldomatic® heat tunnel (Model 7001).

In 3 different tests, 2 duplicate samples of 30 pods from each treatment were placed in 1/2-bu corrugated fiberboard boxes (wax-coated) and stored in controlled temperature rooms maintained at 7.2°C and 85 to 92% relative humidity. All pods were evaluated for visual symptoms of decay, surface color development and pod firmness after 1-, 2-, and 3-week storage, and again after 5 additional days at 15.6°C. Decay was identified visually or by laboratory procedures and was categorized as bacterial soft rot (BSR) or fungal decay by type. When more than a single pathogen caused decay on a single pod, the most predominant decay (most surface area affected) was scored. Pods having decay were removed for identification and eliminated from the test.

Surface color was subjectively determined by visually estimating the percentage of surface area that was nongreen: 1 = 0%, and green; 2 = <2%; 3 = 2-10%; 4 = 11-25%; 5 = 26-50%; 6 = 51-75%; 7 = >75% and yellow/orange; and 8 >75% and red in color. Pod firmness was determined by scoring the degree a pod yields to moderately applied finger pressure; i.e., 5 = very firm (no yield to pressure), 4 = firm (slight yield), 3 = moderately firm (moderate yield), 2 = slightly firm (yields greatly to pressure), and 1 = flaccid (no resistance to pressure).

All data were statistically analyzed by analysis of variance procedures to test the main effects of the three factors (film; CL and IM) and their interactions.

Results and Discussion

Cumulative percentage of decay by type of pathogen (bacterial or fungal) during weekly storage periods is presented in Table 1. No treatment (TRT) effectively controlled the development of BSR during storage. For unknown reasons, BSR was significantly increased by an average of 3.8% in treatments with IM (8.3%) compared with treatments without IM (4.5%) after 2-week storage at 7.2°C. Following 3 weeks at 7.2°C plus 5 days at 15.6°C storage BSR was significantly increased by an average of 10.3% in treatments with IMFL (35.0%) compared with treatments without IMFL (24.7%). There was no other significant main effect or interaction effect on BSR during storage.

Fungal decay was caused mostly by *Alternaria* sp. and *Botrytis* sp. and generally developed slowly during 7.2°C storage. After 3 weeks at 7.2°C storage, the effect of IM significantly reduced fungal decay by an average of 1.6% in treatments when IM was present (1.3%) compared to treatments without IM (2.9%). Following the final inspection (3 weeks at 7.2°C + 5 days at 15.6°C) both IM and IMFL significantly reduced the average percentage of fungal decay by 9.2 and 10.9% respectively, when present in treatments (effect of IM = effect of IM minus effect of no IM = average of treatments 5, 6, 7, 8 minus average of treatments 1, 2, 3, 4 = 5.4 – 14.6 = –9.2; effect of IMFL = effect of IMFL minus effect of no IMFL = average of treatments 2, 4, 6, 8 minus average of treatments 1, 3, 5, 7 = 4.5 – 15.4 = –10.9%). There was also an interaction between IM and IMFL; i.e., the effect of IM depends on the level of IMFL and vice-versa. The effect of IM in the absence of IMFL was 7.0 (Treatments 5 + 7) minus 23.9 (Treatments 2 + 3) divided by 2 = –8.4%, while the effect of IM in the presence of IMFL was 3.7 (Treatments 6 + 8) minus 5.3 (Treatments 2 + 4) divided by 2 = –0.8%. Consequently, the interaction effect = [–8.4 – (–0.8)] = –7.6%. Thus, both IM and IMFL were effective in the control of fungal decay and effectiveness of each depended on the level of the other. No other treatment was effective in reducing fungal decay.

For total decay, the main effects of IM and IMFL were not significant, but the interaction of IM and IMFL was significant due to a reversal of the effect of IM. Interpretation of this effect is made somewhat clearer by tabulating the average values for percentage of total decay for each simple factor:

	Without IM	With IM
Without IMFL	46.8	33.6
With IMFL	37.8	41.3

The effect of IM was equal to (33.6-46.8)/2 = –6.6 in the absence of IMFL and was equal to (41.3-37.8)/2 = 1.8 in the presence of IMFL. Hence, when the effect of IM is averaged over these two levels of IMFL, the main effect of IM is not significant. These results for total decay are because BSR was increased due to the IM effect (at 2 weeks) and the IMFL effect (26 days) whereas fungal decay was decreased due to the IM effect (26 days) and the IMFL effect (26 days). Also, the incidence of BSR is relatively much greater than the incidence of fungal decay (except treatment 1) following 26 days' storage.

Average surface color and pod firmness indices by treatment are presented in Table 2. The IMFL effect was the only significant effect expressed for either surface color development or pod firmness. Color development was slowed by 0.25 index units by the presence of IMFL after the 5 days at 15.6°C storage. Pod softening was consistently reduced during storage at each evaluation when pods were wrapped in IMFL compared to pods nonwrapped. The effect of IMFL on color development and pod softening is

Table 1. Effect of chemicals and film wrapping to control decay of bell peppers during storage.

Treatments	Percentage of decay by type: Bacterial soft rot, Weeks 1	2	3	+5 days	Fungal rot[z], Weeks 1	2	3	+5 days	Total decay, Weeks 1	2	3	+5 days
	at 7.2°C	at 7.2°C	at 7.2°C	at 15.6°C	at 7.2°C	at 7.2°C	at 7.2°C	at 15.6°C	at 7.2°C	at 7.2°C	at 7.2°C	at 15.6°C
1. Control (no film)	1.1	2.8	5.6	21.7	0.0	1.1	2.8	25.6	1.1	3.9	8.4	47.3
2. IMFL[y]	2.2	4.5	12.2	35.7	0.6	2.8	2.8	5.6	2.8	7.3	15.0	41.3
3. CL[y] (1000 ppm)	3.3	5.6	7.7	24.1	0.6	2.2	4.4	22.1	3.9	7.8	12.1	46.2
4. CL + IMFL	3.3	5.0	11.0	29.2	0.6	1.1	1.7	5.0	3.9	6.1	12.7	34.2
5. IM[y] (500 ppm)	3.9	7.8	10.6	25.6	0.6	0.6	1.1	7.8	4.5	8.4	11.7	33.4
6. IM + IMFL	2.9	5.6	12.9	33.3	0.6	0.6	0.6	2.3	3.5	6.2	13.5	35.6
7. CL + IM	5.1	9.0	12.8	27.5	1.1	2.2	2.8	6.2	6.2	11.2	15.6	33.7
8. CL + IM + IMFL	8.3	10.6	15.5	41.9	0.0	0.6	0.6	5.1	8.3	11.2	16.1	47.0
Main effects[x, w]												
IM vs. no IM	NS	3.8	NS	NS	NS	NS	–1.6	–9.2	NS	NS	NS	NS
IMFL vs. no IMFL	NS	NS	NS	10.3	NS	NS	NS	–10.9	NS	NS	NS	NS
Interactions												
IMFL * IM	NS	NS	NS	NS	NS	NS	NS	7.6	NS	NS	NS	–8.4

[z]Decay principally due to *Alternaria* sp. and *Botrytis* sp.
[y]IMFL = imazalil film; CL = chlorine; IM = imazalil solution.
[x]Analysis of variance procedures: percentage values are statistically different from 0 at 5% level (*); NS = not significant.
[w]Main effects and interaction effects not shown were not significant for all storage periods.

Table 2. Effect of decay-control chemicals and film wrapping on color and firmness of bell peppers during storage.

Treatments	Color index[z]				Firmness index[y]			
	Weeks				Weeks			
	1	2	3	+5 days	1	2	3	+5 days
	at 7.2°C			at 15.6°C	at 7.2°C			at 15.6°C
1. Control (no film)	1.06	1.13	1.29	1.89	4.84	4.77	4.64	4.10
2. IMFL[x]	1.03	1.09	1.25	1.53	4.88	4.91	4.86	4.81
3. CL[x] (1000 ppm)	1.04	1.19	1.30	1.98	4.83	4.78	4.67	4.17
4. CL + IMFL	1.06	1.14	1.31	1.54	4.94	4.90	4.77	4.62
5. IM[x] (500 ppm)	1.07	1.13	1.27	1.82	4.74	4.72	4.63	4.25
6. IM + IMFL	1.08	1.20	1.33	1.68	4.94	4.91	4.79	4.78
7. CL + IM	1.02	1.17	1.30	1.75	4.91	4.74	4.65	4.32
8. CL + IM + IMFL	1.05	1.12	1.29	1.68	4.91	4.87	4.85	4.70
Main effects[w,v]								
IMFL vs. no IMFL	NS	NS	NS	-0.25	0.09	0.15	0.17	0.52

[z]Color index; weighted average: 1 = 100% green, 2 = <2% nongreen of surface area.
[y]Firmness index: 5 = firm hard; 4 = moderately firm.
[x]IMFL = imazalil film; CL = chlorine; IM = imazalil solution.
[w]Analysis of variance procedures: index unit values are statistically different from 0 at the 5% level (*); NS = nonsignificant.
[v]Main effects and interaction effects not shown were not significant for all storage periods.

consistent with previous studies (12) reporting the effects of similar but non-IM impregnated plastic films on pepper quality factors.

In summary the major findings of this study are: 1) BSR was not effectively controlled by any treatment; 2) the effect of IMFL increased the incidence of BSR after 3 week at 7.2°C plus 5 days at 15.6°C storage; 3) IM and IMFL were partially effective in the control of fungal decay; the combination of IM and IMFL were more effective than IM or IMFL alone; 4) for total decay, no treatment was effective; 5) wrapping peppers in IMFL consistently reduced pod softening during storage and color development after extended storage; 6) this study supports previous work that reported decay principally caused by BSR is a seriously limiting factor and prohibits relatively long-term (3 weeks) storage of bell peppers; and 7) shipment of Florida peppers successfully to distant markets that requires more than 2-weeks delivery on a consistent basis is not recommended due to excessive losses caused by decay.

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