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Evaluation of Ethanedial Dioxime (Pik-Off) as an Abscission Agent on Florida Oranges Used for Processing[1]

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Abstract. **Pik-Off (PO), a Ciba-Geigy Corp. product, has been field evaluated under an Environmental Protection Agency (EPA) experimental permit. Although PO does not usually produce as good abscission as some other chemicals, it appears satisfactory for many uses. From a cost and residue standpoint, PO appears to be in an advantageous position, and it is compatible with the 'Valencia' cultivar (*Citrus sinensis* (L.) Osbeck). PO should not be used with surfactants. Its effect is decreased by rain (within 24 hours of application) and low temperatures. PO is restricted by label as to total quantity which can be applied per ha. However, results of a series of volume versus concentration field tests showed that increased amounts of material per ha substantially improved abscission performance, particularly on larger trees.**

Ethanedial dioxime (formerly CGA-22911) was patented by Dr. Merrill Wilcox, University of Florida, Gainesville, as an abscission agent (abscisor) (5) for citrus fruits, and it has been developed commercially by Ciba-Geigy Corp. under the trade name Pik-Off (PO). The compound has proven effective for this purpose (4, 6, 12), although it is the only member of its chemical class which has done so (6). The basis of selection of ethanedial dioxime for evaluation was its structure which was believed capable of furnishing 2-carbon fragments in degradation and therefore promising as an abscission agent (6). It appears now, however, that the mode of action of PO is probably similar to other citrus abscisors which superficially injure fruit peel tissue and cause ethylene to be formed as a result of this wound response (9).

PO has some excellent attributes as an abscisor including being acceptable on the late 'Valencia' orange cultivar (4, 12), simple chemical structure which makes it more inexpensive to produce, and residue problems appear to be considerably less than with other abscisors. Its principal problem has been erratic abscission performance, and it has not been generally accepted by growers who prefer 5-chloro-3-methyl-4-nitro-1H-pyrazole (Release). The Florida citrus industry (Florida Department of Citrus) has purchased worldwide rights to Release as an abscission agent. However, EPA clearance will depend on whether toxicological studies show no carcinogenic properties. Therefore, considerable research effort has been expended on PO, as well as other potential abscisors. This paper is a summary of information relating to PO.

Materials and Methods

Evaluations were based on standardized procedures reported previously (2). Branch tests were made in commercial groves near Lake Alfred, Florida. Materials were applied to individual branches on 3 separate 'Valencia' orange trees, each containing 20–30 mature fruit, with air-pressurized hand sprayers at the rate of 1 liter per branch. Whole-tree spray tests near Lake Alfred and LaBelle, Florida, consisted of randomized plots of 3 or more trees, and fruit samples were taken from trees in or near the centers of these plots. Fruit removal force (FRF) measurements were recorded on 15 fruit per tree 4–5 days following treatment using a modified hand-held Hunter spring mechanical force gauge. Fruit drop was also determined at that time. Surfactant was used with PO only as indicated (0.1% Ortho X-77 was used with all other abscisors tested). Whole trees were sprayed either with a FDOC modified AG-Tec air blast sprayer, an FMC 757 (double oscillating volute) Speed Sprayer, or with a commercial FMC hand sprayer as indicated. All trees, unless otherwise indicated, were planted on a 7.6 x 7.6 m setting with 175 trees per ha. Trees in central Florida (Lake Alfred area) were about 6 m in height and those at LaBelle were about 3.7 m in height.

PO has a label restriction of 11.8 liters per ha (1). This amount was exceeded, as indicated, in order to obtain maximum fruit abscission as needed for a particular experiment. Formulation of PO used was 120 g active ingredient per liter.

Results and Discussion

Many field tests, large and small, have been conducted with PO and other abscission chemicals during the past several years and voluminous data are available. Results typical of these tests are shown in Table 1. Pull forces were usually higher and fruit drop numbers usually lower with PO compared to Release, Acti-Aid (cycloheximide or AA) or combinations. Occasionally, PO produced loosening and fruit drops comparable to other abscission compounds and combinations (Table 2). Although fruit drop in this particular experiment was slightly less with PO, the percent fruit recovery, using an air shaker for harvesting, was identical. The slight differences in fruit loosening (FRF and fruit drop) were not reflected in differences in fruit recovery when the trees were harvested with mechanical shakers.

The principal reason that PO is erratic and often produces poor abscission is probably related to its ethylene production pattern (2). Fruit treated with PO may produce as much or more ethylene as fruit treated with other abscission chemicals. Ethylene production in PO-treated fruit drops off rapidly, however, and retightening occurs. Ethylene production has been correlated with fruit ab-

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Table 1. Comparison of Pik-Off with other abscission chemicals applied to 'Hamlin' oranges, Lake Alfred, Florida[z]

Treatment	Concn[y,x] (ppm)	Fruit removal force (FRF) (kg ± SD)	Avg fruit drop (no./tree)
Pik-Off	300[y]	2.56 ± 1.40	38
Acti-Aid	5+		
Release	100+		
Sweep	250	1.49 ± 1.38	353
Release	125	1.52 ± 1.05	265
Acti-Aid	20	1.69 ± 1.18	82
Control	—	6.28 ± 1.81	0

[z]Sprays were applied Dec. 29, 1977 and FRF measurements were made Jan. 3, 1978. Whole-tree tests. Surfactant (Ortho X-77 at 0.1%) was used with all sprays except Pik-Off. Volume was 7098 liters/ha. Sweep is a product of the Diamond Shamrock Corp.; Acti-Aid is a product of the Upjohn Company; Release is a product of Abbott Laboratories.
[y]Exceeds label recommendations of 11.83 liters active PO/ha.

Table 2. Comparison of Pik-Off with Release + Acti-Aid combination on 'Hamlin' oranges, Labelle, Florida[z]

Treatment	Concn (ppm)	FRF (kg ± SD)	Fruit drop (%)	Fruit recovery[x] (%)
Pik-Off	300[y]	0.92 ± 0.62	76	99.4
Release	100+			
Acti-Aid	1.5	0.87 ± 0.44	97	99.4
Control	—	5.44 ± 1.18	0.5	99.1

[z]Sprays were applied Feb. 22, 1979 and FRF measurements were made Feb. 27, 1979. Surfactant (Ortho X-77 at 0.1%) was included with Release-Acti-Aid combination only. Volume of spray was 7098 liters/ha. Leaf drop with Pik-Off treatments was essentially zero but averaged 4% for Release-Acti-Aid combination. Whole-tree tests.
[y]Exceeds label recommendations.
[x]Harvest system used was Florida Department of Citrus experimental air shaker using a conical scanning air delivery system to remove fruit. USDA sweep-pickup equipment was used to complete harvest operation. Removal efficiency was compared to that obtained with a commercial crew from adjacent handpicked block.

scission responses of several abscission chemicals, and sustained production, in addition to adequate peak production, is usually necessary to lower the FRF and to increase fruit drop (2). Heavy fruit drop is a consequence of increasing abscission activity (7) and must be taken into account in development of mechanical harvesting systems for citrus fruits.

PO appears to be more sensitive to adverse weather conditions than most of the other chemicals currently used (2). Ciba-Geigy Corp. has taken this into consideration with its current label which prohibits applications when temperature is below 18.3°C (1). This is more restrictive than is necessary for other abscission chemicals.

Addition of surfactants and additives, including urea, was not beneficial and usually decreased the abscission response to PO (Table 3). The chemical Extend (a nitrogen regulator product manufactured by Kalo Laboratories, Kansas City, MO 64114) was included because of its use as a stabilizer of nitrogen compounds. It was hoped that the compound would interact with nitrogen groups on the glyoxime molecule, perhaps slow its breakdown and prolong ethylene production.

Field reports (4) indicated that addition of surfactant to PO can cause increased leaf drop. Additives also increased leaf drop in tests summarized in Table 3. Improved abscission response to PO has been reported with the addition of AA or Sweep (chlorothalonil) (3), however, in other tests (2) these additions gave no advantage. Other abscission agents, Release and AA, work better when surfactants are added. However, this is not the case with (2 chloroethyl)phosphonic acid (ethephon) (12). Although addition of surfactants and additives to PO may still be feasible, results in my tests, and others by Ciba-Geigy, have not been encouraging. The PO label (1) prohibits addition of surfactants and this direction appears to be valid.

Table 3. Effects of added ingredients on the abscission activity of Pik-Off with 'Valencia' oranges, Lake Alfred, Florida[z]

Treatment	Concn (ppm)	Adjuvant[y]	FRF (kg ± SD)	Avg fruit drop (no./tree)
Pik-Off	300		2.30 ± 1.58	76
Pik-Off	180		3.91 ± 1.39	8
Pik-Off	180	Ortho X-77	3.82 ± 1.13	4[x]
Pik-Off	180	Component B	3.83 ± 1.28	11[x]
Pik-Off	180	Pace	3.96 ± 0.97	5[x]
Pik-Off	180+			
Urea	600	Extend	5.12 ± 1.22	2
Pik-Off	180+			
Urea	600		6.08 ± 2.84	5
Pik-Off	180+			
Urea	600	Ortho X-77	6.39 ± 2.25	3
Control			7.37 ± 1.87	5

[z]Sprays were applied April 13, 1978 and FRF measurements were made April 17, 1978. All surfactants were applied at 0.1%. Branch tests.
[y]Ortho X-77 is a product of Chevron Chemical Company; Component B is a product of the Upjohn Company; Pace is a product of Amchem Products, Inc.; Extend is a product of Kalo Laboratories, Inc.
[x]Increased leaf drop substantially.

Concentration vs. volume of spray has been tested extensively. Increasing both volume of spray applied and concentration of PO produced lower FRF readings and increased fruit drop, but the best responses were from concentrations which exceeded label recommendations (Table 4). An additional experiment was performed to determine whether the response was due to increased concentration or spray coverage (Table 5). An attempt to increase fruit loosening by splitting the rate (amount) of material in 2 applications was also made to obtain better coverage because of the increased amount of water. In these experiments, increasing spray volume without an increase in material applied was not beneficial, and increasing the number of applications was ineffective. A thorough drenching of the trees with a hand sprayer using a con-

Table 4. The effect of Pik-Off concn and spray volume on abscission of 'Valencia' oranges, Lake Alfred, Florida[z]

Concn (ppm)	Spray (liters/ha)	FRF (kg ± SD)	Avg fruit drop (no./tree)	Rank
180	4732	4.01 ± 1.77	43	9
180	7098	3.49 ± 2.08	65	8
180	9464[x]	2.50 ± 1.61	95	4
240	4732	3.22 ± 2.02	62	7
240	7098[x]	2.49 ± 1.66	108	3
240	9464[x]	2.53 ± 1.70	206	5
300	4732[y]	2.78 ± 1.67	93	6
300	7098[x]	1.68 ± 1.20	218	2
300	9464[x]	1.46 ± 1.03	259	1
Control	--	7.61 ± 1.91	7	10

[z]Sprays were applied April 21, 1978 and FRF measurements made April 25, 1978. Whole-tree tests.
[y]Maximum allowable chemical per ha according to label recommendations.
[x]Exceeds label recommendations. Conversion factors: 4732 liters/ha = 500 gal/acre; 7098 liters/ha = 750 gal/acre; 9464 liters/ha = 1000 gal/acre.

Table 5. The effect of Pik-Off concn, spray volume, and splitting applications on abscission of 'Valencia' oranges, Lake Alfred, Florida[z]

Concn (ppm)	Spray (liters/ha)	FRF (kg ± SD)	Avg fruit drop (no./tree)	Rank
180	4732	4.49 ± 2.27	57	5
90	9464	6.12 ± 1.97	25	7
300[y]	4732	3.27 ± 1.86	159	2
150[y]	9464	4.37 ± 1.98	89	4
300[x]	9464	1.70 ± 1.57	412	1
90 + 90	4732 + 4732	5.47 ± 2.58	26	6
150 + 150	4732 + 4732	3.78 ± 2.18	93	3
Control	--	6.53 ± 1.71	0	8

[z]Single application sprays were applied May 26, 1978; split (double) application sprays were applied May 25 and May 26, 1978. FRF measurements were made May 30, 1978. Whole-tree tests.
[y]Maximum allowable chemical per ha according to label recommendations.
[x]Exceeds label recommendations. Applied by hand sprayer.

Table 6. Injury to immature 'Valencia' orange fruit following applications of Pik-Off, Lake Alfred, Florida[z]

Application date	Avg fruit size (cm ± SD)	Injury
May 1	0.61 ± 0.21	None
May 8	1.01 ± 0.27	None
May 15	1.60 ± 0.41	None
May 22	2.01 ± 0.35	None
May 30	2.43 ± 0.55	None
June 6	2.85 ± 0.39	None
June 13	3.09 ± 0.40	None
June 19	3.57 ± 0.60	Burn
June 26	3.64 ± 0.56	Burn

[z]Pik-Off was applied at 300 ppm. Branch test.

centration greater than recommended by label, and greatly exceeding recommended spray volume per ha, produced the lowest FRF and greatest fruit drop (Table 5).

Field experience has shown that PO can injure immature 'Valencia' fruit. A final experiment was conducted to determine at what stage of growth this occurs. No injury was observed until average fruit diameter reached 3.57 cm (Table 6). PO has a label restriction (1) which prohibits its use on immature fruit larger than 2.54 cm average diameter. This label restriction appears to be correct as the bloom period for 'Valencia' oranges can occur over several weeks, often resulting in considerable fruit size variation. Only a very small proportion of total fruits as large as 3.57 cm diameter could be expected when average diameter is 2.54 cm. According to computed standard deviations (Table 6), immature fruit size appears to be normally distributed according to statistical concepts.

PO, though somewhat inferior to some other abscisors, is a satisfactory chemical for many harvesting purposes. It can be used with limb shakers and as a harvest aid for hand pickers (10, 11). The compatability with 'Valencia' is a very important asset. PO is not a particularly good abscission agent when air shakers are used because it usually does not loosen fruit sufficiently to achieve adequate fruit recovery with this harvest method (10). It may be satisfactory in areas such as south Florida, however, where the number of degree-hours is substantially higher than in central Florida and where in recent field tests PO has performed well with air shakers (11).

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