Rubidium is very similar to potassium, a highly mobile element, but Sr which is closely related to Ca and much less mobile than K, was also transferred through rootgrafts. As in split-root system experiments (Shannon and Zaphrir, 1957; Duke et al., 1986), mineral elements, after some initial delay, were readily transported through rootgrafts from one root system to the other. The possibility of transfer of compounds other than infectious agents must be taken into account in rootgraft situations.

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HORTICULTURAL SPRAY OIL EFFECTS ON DEGREENING OF CITRUS FRUIT[1]

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Abstract. **Two percent (v/v) of FC 435-66 and FC 455-66 horticultural spray oils were applied using a hand gun sprayer to 'Hamlin' orange trees, 'Marsh' grapefruit trees, and Navel orange trees during the fall of 1992. There was 0.02% of an emulsifier in the oil spray solutions and an emulsifier only spray check. Fruits were harvested 0, 7, and 14 days after spraying. Rind color, °Brix, % acid, and °Brix/acid ratio were measured. Fruits were degreened for 72 and/or 96 hours. Rind color was then measured again. Results indicated that there was little effect of oil on the degreening or internal fruit quality of 'Hamlin' oranges and 'Marsh' grapefruit regardless of oil type. With navel orange, no significant effects on degreening were found on fruit harvested 0 days after treatment or with internal fruit quality measures at all harvest times. Oil treated fruit harvested 7 and 14 days after spraying had some reductions in degreening rate over the check. The reduction was most pronounced with fruit harvested 14 days after spraying with 72 hours of degreening.**

Horticultural spray oils are considered to be environmentally safe and are finding widespread use (Johnson, 1985). Horticultural spray oils have been used for many years to control greasy spot disease on citrus (Williamson et. al., 1991). Recent recommendations indicate that "a second application" [of oil] "may be required during August or September to control infection on the more susceptible cultivars like grapefruit and Hamlins, especially when infected leaf litter persists" (Williamson et. al., 1991). However, spray oil can delay citrus fruit degreening (Yothers and McBride, 1929) (Grierson and Newhall, 1960; Harding, 1953; Trammel and Simanton, 1966; Vakis, 1978; Winston, 1942). In addition, applications of horticultural spray oils closer to the time of harvest were found to delay degreening more than earlier sprays (Grierson and Newhall, 1960) on both oranges (Winston, 1942; Harding, 1953) (Trammel and Simanton, 1966) and grapefruit (Vakis, 1978). Some of the early work was done using horticultural spray oils of questionable quality (Harding, 1953; Winston, 1942) and high in unsulfonated residues. Trammel and Simanton (1966) found that effects on degreening were greater with increased rates of oil and with the use of heavier oils (oils with a high mid distillation point).

Little work has been done on what varieties are sensitive to oil induced inhibition of degreening. It has been observed that navel oranges are more sensitive than other oranges to oil reduction of degreening (Richard Stoll, personal communication). This study was undertaken to determine if there were any adverse effects on the degreening process on fresh market fruit treated with oil prior to harvest.

Materials and Methods

1. Effect of oil sprays on degreening of 'Hamlin' orange. The effect of time of application and of multiple sprays of FC-435-66 horticultural spray oil on degreening of 'Hamlin' orange trees on sour orange rootstock was studied in a grove near Indiantown, FL. Five treatments were applied to sets of five 2 tree plots (giving 50 treated trees altogether). Treatments were a summer oil spray, a fall oil spray, a summer plus fall oil spray and a spring plus summer plus fall oil spray. All oil spray solutions consisted of 2% FC-435-66 oil (Mid Distl. pt. 10 mm Hg 435° F). There was a 0.02% emulsifier check, sprayed in summer. The treatments were applied by hand gun to drip. The rate was 28 liters of spray solution per tree (139 liters/ha of oil; 14.9 gal./acre of oil; 6,968 liters/ha of spray solution; 745 gal./acre of spray solution). The spring, summer, and fall treatment times were on 7 May, 1992, 8 July, 1992, and 17,18 Sept., 1992. The treatment plots were in a completely randomized design.

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After the fall spray, 20 fruit each were harvested 0, 7, and 14 days after application. Fruit color was determined using a Hunter Color Difference Meter Model D 25A (Stewart and Wheaton, 1971) immediately after harvest on 10 fruit on a 2.54 cm diameter circle along the equatorial plane of the fruit. Color was read again after 96 hours of exposure to 5-13 ppm ethylene in a degreening room (RH 92%, 29.4° C). Degreening was quantified as the % change in A/B ratio. The ethylene concentration was monitored daily using gas chromatography and the rate of degreening was calculated. The fruit used for degreening was then placed for 1 week at 60° F and the color read again. Percent acid and °brix were determined on 10 fruit (Wardowski et al., 1979). Data were analyzed using Duncan's multiple range test.

2. Effect of dual oil sprays on degreening of 'Marsh' Grapefruit. White 'Marsh' grapefruit in a grove near Fellsmere, FL were sprayed once by the grower with 93.5 liters FC 435-66 oil/ha (10 gal./acre) between 10 July and 10 Aug., 1992. Fifteen trees were treated on 9 Oct., 1992; 5 were treated with 93.5 liters/ha (10 gal./acre) of FC-435-66 oil (containing 1% T-Mulz-FCO emulsifier in the oil), 5 with the same rate of FC-455-88 oil, and 5 were treated with a 0.94 liters/ha rate of emulsifier as a check. The spray volume was 4,676.91 liters/ha (500 gal./acre). The FC-455-88 oil has a higher mid distillation point than FC-435-66 oil and is thus considered a heavier oil. The trees were in a completely randomized design. After the spray, 20 fruit were harvested at 0, 7, and 14 days after application. Fruit color was determined immediately after harvest and again after 96 hours of exposure to 4-11 ppm ethylene in a degreening room (RH 92%,29.4° C). The ethylene concentration was monitored daily using gas chromatography. The fruit used for degreening were then placed for 1 week at 15.6° C and the color read. A/B ratio of % acid and °Brix were determined on 10 fruit. Data were analyzed using Duncan's multiple range test.

3. Effect of oil sprays on degreening of navel orange. This study was done in the same way as the second study except that each replication consisted of 2 trees, the trees were navel oranges, the spray volume was 4,116 liters/ha (440 gal./acre) and the trees were only sprayed once with oil.

Results

1. Effect of oil sprays on degreening of 'Hamlin' orange. Results after 96 hours of degreening indicated little effect on 'Hamlin' oranges (Table 1). After an additional week of storage at 15.6° the single summer sprayed fruit showed less degreening than the multiple fall oil applications with fruit collected the same day as treatment (Table 2). No such effects were noted on fruit collected 7 and 14 days after treatment. There was no effect of the oil sprays on the acid, °Brix or ratio of Acid/°Brix (Data not shown).

2. Effect of dual oil sprays on degreening of 'Marsh' grapefruit. Results with 'Marsh' grapefruit indicated that there was no effect of oil sprays on degreening (Tables 3). Little effect was found with measures of internal fruit quality except with the acid results 7 days after harvest where the oil treated fruits did have a significant reduction in % acid (Table 4).

3. Effect of oil sprays on degreening of navel orange. No significant effects of oil on degreening was noted on fruit harvested on the same day as the treatment. However, in the case of 72 hours of degreening, differences began to emerge with fruit collected 1 week after spraying and became stronger 2 weeks

Table 1. Results of 'Hamlin' oranges sprayed with FC 435-66 oil and then degreened for 96 hours. Treatments consisted of a check (a spray with 0.02% T-MULZ-FCO emulsifier), a spray on 8 July (Summer Spray), a spray on 17, 18 Sept. (Fall Spray), Sprays on 8 July and 17, 18 (SUMFALL Sprays), and Sprays on 7 May, 8 July, and 17, 18 Sept. (SPSUMFALL Sprays). Trees were sprayed with a rate of 139 liters of oil/ha Fruit samples were taken on the same day (17, 18 Sept.), 7 days and 14 days afterwards.

Treatment	Change in ab ratio	% Change in ab[z]
Fruit collected same day as treatment		
Check[y]	0.398 a[x]	55.15 a
Summer Spray	0.372 a	51.60 a
Fall Spray	0.362 a	53.06 a
SUMFALL Sprays	0.392 a	56.61 a
SPSUMFALL Sprays	0.410 a	57.42 a
Fruit collected 7 days after treatment		
Check	0.380 a	55.25 a
Summer Spray	0.364 a	52.49 a
Fall Spray	0.352 a	50.78 a
SUMFALL Sprays	0.376 a	52.89 a
SPSUMFALL Sprays	0.378 a	53.02 a
Fruit collected 14 days after treatment		
Check	0.454 a	64.72 a
Summer Spray	0.422 a	61.12 a
Fall Spray	0.404 a	57.89 a
SUMFALL Sprays	0.454 a	63.62 a
SPSUMFALL Sprays	0.422 a	58.02 a

[z]ab refers to the A/B ratio. The higher the number, the more orange the color.
[y]The check consisted of a spray with 0.02% T-MULZ-FCO emulsifier.
[x]Mean separation in columns by Duncan's Multiple Range Test, 5% level.

Table 2. Results of 'Hamlin' oranges sprayed with FC 435-66 oil, then degreened for 96 hours and then stored for 1 week at 15.6° C. Treatments consisted of a check (a spray with 0.02% T-MULZ-FCO emulsifier), a spray on 8 July (Summer Spray), A spray on 17, 18 Sept. (Fall Spray), Sprays on 8 July and 17, 18 Sept. (SUMFALL Sprays), and Sprays on 7 May, 8 July, and 17,18 Sept. (SPSUMFALL Sprays). Trees were sprayed with a rate of 139 liters of oil/ha Fruit samples were taken on the same day (17, 18 Sept.), 7 days and 14 days afterwards.

Treatment	Change in ab ratio	% Change in ab[z]
Fruit collected same day as treatment		
Check[y]	0.470 bc[x]	65.12 b
Summer Spray	0.456 c	63.30 b
Fall Spray	0.502 abc	73.62 a
SUMFALL Sprays	0.516 ab	74.47 a
SPSUMFALL Sprays	0.542 a	75.86 a
Fruit collected 7 days after treatment		
Check	0.562 a	81.71 a
Summer Spray	0.530 a	76.48 a
Fall Spray	0.532 a	76.75 a
SUMFALL Sprays	0.554 a	77.97 a
SPSUMFALL Sprays	0.556 a	78.09 a
Fruit collected 14 days after treatment		
Check	0.676 ab	96.31 a
Summer Spray	0.662 ab	95.61 a
Fall Spray	0.632 b	90.60 a
SUMFALL Sprays	0.710 a	99.49 a
SPSUMFALL Sprays	0.670 ab	92.05 a

[z]ab refers to the A/B ratio. The higher the number the more orange the color.
[y]The check consisted of a spray with 0.02% T-MULZ-FCO emulsifier.
[x]Mean Separation in columns by Duncan's Multiple Range Test, 5% level.

Table 3. Results of 'Marsh' grapefruit sprayed with horticultural spray oils, then degreened for 72 hours and then given 1 week of storage at 15.6° C. Trees were sprayed with a 93.5 liters of oil/ha rate on 9 Oct., 1992 and fruit samples were taken on the same day, 7 days and 14 days afterwards.

Treatment	Check[z]	FC 435-66	FC 455-88
72 hours of degreening			
Fruit collected same day as treatment			
change in ab[y]	0.376 a[x]	0.384 a	0.370 a
% change in ab	79.99 a	77.07 a	76.64 a
Fruit collected 7 days after treatment			
change in ab	0.402 a	0.406 a	0.394 a
% change in ab	87.11 a	83.65 a	83.55 a
Fruit collected 14 days after treatment			
change in ab	0.390 a	0.414 a	0.400 a
% change in ab	87.45 a	86.29 a	84.54 a
72 hours of degreening and 1 week of storage			
Fruit collected same day as treatment			
change in ab	0.436 a	0.456 a	0.446 a
% change in ab	92.61 a	91.57 a	92.08 a
Fruit collected 7 days after treatment			
change in ab	0.416 a	0.434 a	0.412 a
% change in ab	90.12 a	89.42 a	87.30 a
Fruit collected 14 days after treatment			
change in ab	0.396 a	0.432 a	0.420 a
% change in ab	88.76 a	90.00 a	88.72 a

[z]The check consisted of a spray with 0.02% T-MULZ-FCO emulsifier.
[y]ab refers to the A/B ratio. The higher the number, the more orange the color.
[x]Mean separation in rows (comparing the two oils and the check) by Duncan's Multiple Range Test, 5% level.

Table 4. Internal fruit quality results of 'Marsh' grapefruit sprayed with horticultural spray oils. Trees were sprayed with a 93.5 liters of oil/ha rate on 9 Oct., 1992 and fruit samples were taken on the same day, 7 days and 14 days afterwards.

Treatment	Acid[z]	°Brix	Ratio[y]
Fruit collected same day as treatment			
Check[x]	1.340 a[w]	10.148 a	8.052 a
FC 435-66 oil	1.480 a	9.996 a	6.759 a
FC 455-88 oil	1.460 a	10.252 a	7.027 a
Fruit collected 7 days after treatment			
Check	1.458 a	10.212 a	7.004 a
FC 435-66 oil	1.362 c	9.972 a	7.322 a
FC 455-88 oil	1.400 b	10.120 a	7.233 a
Fruit collected 14 days after treatment			
Check	1.436 a	10.367 a	7.227 a
FC 435-66 oil	1.378 a	10.096 a	7.330 a
FC 455-88 oil	1.430 a	10.326 a	7.244 a

[z]Percent acid.
[y]°Brix/percent acid.
[x]The check consisted of a spray with 0.02% T-MULZ-FCO emulsifier.
[w]Mean separation in columns by Duncan's Multiple Range Test, 5% level.

after spraying (Table 5). The same fruit degreened for 96 hours, had no significant differences. However, with an additional week of storage at 15.6° C oil treated fruit showed reductions in degreening with fruit collected 7 and 14 days after treatment (Table 6). Again there was no effect of the oil sprays on the acid, °Brix or ratio of Acid/°Brix (data not shown).

Table 5. Results of navel orange sprayed with horticultural spray oils and then given 72 and 96 hours of degreening. Trees were sprayed with a 93.5 liters of oil/ha rate on 9 oct., 1992 and fruit samples were taken on the same day, 7 days and 14 days afterwards.

Treatment	Check[z]	FC 435-66	FC 455-88
72 hours of degreening			
Fruit collected same day as treatment			
change in ab[y]	0.526 a[x]	0.474 a	0.492 a
% change in ab	80.24 a	72.72 a	75.21 a
Fruit collected 7 days after treatment			
change in ab	0.578 a	0.518 a	0.506 a
% change in ab	87.14 a	82.23 a	78.59 a
Fruit collected 14 days after treatment			
change in ab	0.600 a	0.540 b	0.516 b
% change in ab	93.55 a	85.36 ab	81.24 b
96 hours of degreening			
Fruit collected same day as treatment			
change in ab	0.614 a	0.548 a	0.572 a
% change in ab	93.66 a	84.07 a	87.77 a
Fruit collected 7 days after treatment			
change in ab	0.652 a	0.592 a	0.582 a
% change in ab	98.27 a	93.98 a	90.37 a
Fruit collected 14 days after treatment			
change in ab	0.692 a	0.628 a	0.606 a
% change in ab	107.86 a	99.21 a	95.37 a

[z]The check consisted of a spray with 0.02% T-MULZ-FCO emulsifier.
[y]ab refers to the A/B ratio. The higher the number, the more orange the color.
[x]Mean separation in rows (comparing the two oils and the check) by Duncan's Multiple Range Test, 5% level.

Table 6. Results of navel orange sprayed with horticultural spray oils and then given 96 hours of degreening plus 1 week of storage at 15.6° C. Trees were sprayed with a 93.5 liters of oil/ha rate on 9 Oct., 1992 and fruit samples were taken on the same day, 7 days and 14 days afterwards.

Treatment	Check[z]	FC 435-66	FC 455-88
Fruit collected same day as treatment			
change in ab[y]	0.766 a[x]	0.714 a	0.730 a
% change in ab	116.81 a	109.55 a	112.00 a
Fruit collected 7 days after treatment			
change in ab	0.740 a	0.674 b	0.694 ab
% change in ab	111.51 a	107.01 a	107.66 a
Fruit collected 14 days after treatment			
change in ab	0.760 a	0.706 b	0.690 b
% change in ab	118.46 a	111.50 a	108.52 a

[z]The check consisted of a spray with 0.02% T-MULZ-FCO emulsifier.
[y]ab refers to the A/B ratio. The higher the number, the more orange the color.
[x]Mean separation in rows (comparing the two oils and the check) by Duncan's Multiple Range Test, 5% level.

Degreening is one of the most important postharvest treatments to whichearly seasoncitrusfruit are subjected. The duration of degreening is usually between 72 and 96 hours in an atmosphere of 5-10 ppm ethylene, 92-94% relative humidity and 29.4° C (85° F).

Use of FC 435-66 and FC 455-66 spray oils close to harvesting time did not appear to significantly affect the rate of degreening of oranges or grapefruit, as was previously reported (Grierson and Newhall, 1960; Trammel and Simanton, 1966).

Discussion

Since the % change in A/B ratio figure is affected by the variability of the starting point it appeared to be a less sensitive measure of degreening than the simple change in A/B ratio figure.

Significant changes in color were only found with navel oranges. In the case of the 'Hamlin' oranges, they were picked rather early. Thus, it is difficult to extrapolate the results to later picked 'Hamlin' oranges. This was not the case with the 'Marsh' grapefruit. Since the effect on degreening of 'Navel' orange was only seen after 7 days, this indicated that the effect of horticultural oils on citrus fruit may require internal penetration of the oil into the fruit over time.

Although the use of (FC 435-66 and FC 455-66) are considered safe and do not seem to interfere with the degreening process, it is not advisable that they be used at least 2 weeks prior to harvesting to avoid any possible interference with the degreening process.

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EFFECTS OF TIMING AND MULTIPLE APPLICATIONS OF HORTICULTURAL OIL SPRAYS ON CITRUS

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Additional Index Words. Foliar phytotoxicity, Leaf damage, *Citrus sinensis*, hydrocarbons, mineral oils, petroleum oils.

Abstract. **Horticultural spray oils were applied to 'Hamlin' orange trees near Sebring, FL and Indiantown, FL during the spring, summer, and fall in 1992. The rate was 6 to 7 gal of spray solution/tree (2% FC 435-66 horticultural spray oil v/v). Factors determined included fruit weight and diameter, percent juice, rind color, °Brix, percent acid, °Brix/acid ratio, and pounds solids. Few significant effects were found at the Sebring grove (except where there had been the accidental spraying of motor oil in the previous year). The fruit from trees treated on 30 Sept., which had no previous year's damage, had both increased fruit weight and reduced pounds solids compared to the check. In the Indiantown grove, little effect was found except with the °Brix/acid ratio and with fruit diameter. The spring spray produced a significantly higher ratio than the summer + fall spray and spring + summer + fall spray. There was a trend toward sprays earlier in the year having increased fruit diameter.**

Horticultural spray oils (also called petroleum, mineral, white, or narrow range spray oils) have been used widely on numerous pests and crops (Johnson, 1985; Riehl, 1981). Their use on citrus has been somewhat restrained by recommendations based on previously reported phytotoxic responses including reduced soluble solids (Furness, 1981a; Riehl et al., 1956; Trammel and Simanton, 1966; Sinclair et al., 1941; Stofberg and Anderssen, 1949; Thompson and Sites, 1945), reduced yield (Beattie et al., 1989; Bodenheimer, 1951; Dean et al., 1978; Ebeling, 1950; Furness and Maelzer, 1981), increased leaf drop (Ebeling, 1950; Furness, 1981b) and reduced cold hardiness (Knapp et al., 1994; Trammel and Simanton, 1966). Problems with synthetic pesticides such as increased resistance, toxicity to non-target organisms, and problems with registration and current low citrus prices have brought increased attention to horticultural spray oils. They have certain advantages in that they are relatively safe to non-target species and to pesticide operators. They are relatively inexpensive, have a broad spectrum of pesticidal activity, and can be used against several pests at once. They also can be combined with other pesticides either primarily as an adjuvant or as an additional pesticide. In addition, modern horticultural spray oils are more highly refined and less phytotoxic than those used earlier.

Among the factors reported to increase the phytotoxicity of horticultural spray oils on citrus are repeated applications (Dean and Hoelscher, 1971; Dean et al., 1978) and the timing of applications, particularly relating to their use in the fall (Knapp et al., 1994). Thompson and Sites (1945) found a reduction in °Brix with later sprays with 'Hamlin' orange. Oil applied in August prevented the formation of maximum solids. Riehl et al. (1956) found that the most negative oil effects on °Brix were with sprays in late fall and early spring. Tram-

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The term pound solids used in this paper refers to pounds of soluble solids in the juice from a 90 pound box of fruit.