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Effects of Ethephon on Olive Ripening[1]

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Abstract. **Solutions of (2-chloroethyl) phosphonic acid (ethephon) at 1000, 1500, and 2000 ppm were sprayed on trees of 'Giarraffa' olive (*Olea europaea* L.) time midway between the onset of pit hardening, and the maximum respiratory rate induced early pigmentation of drupes. Treatment modified anthocyanins, respiratory ratio (CO_2/O_2), polyphenols, redox potential, total sugars and their composition, linoleic/palmitoleic acid ratio, and dry weight. Pulp/stone ratio, respiratory rate, pH, uronic acids, oil, principal fatty acids, and protein content did not differ from the control. Ethephon applied after the occurrence of the maximum respiratory ratio only reduced the fruit detachment strength. These results confirm the hypothesis which attributes a climacteric model to the attached fruits and a nonclimacteric model to the detached ones. The physiological modifications of fruits ripened with ethephon were similar to those found in the last stage of natural maturation.**

The capacity of ethylene-releasing chemicals to cause early fruit abscission in olives had been demonstrated in numerous trials (3). Recent studies on the thinning of olive fruits using ethephon showed that it may induce early pigmentation in drupes when sprayed immediately after fruit set (9). Ethylene-releasing chemicals cause early ripening in climacteric fruits, both attached and detached, but only if treated during the preclimacteric period (16). It also causes early ripening in nonclimacteric fruit (i.e., cherry and grape) when applied only a few days before normal ripening (2, 12, 14).

Olive tree fruits do not have a definite maturation pattern. However, it has been proposed that olives area typically climacteric when attached and nonclimacteric when detached (10). Here we report further observations on the respiratory patterns of olives, and the effects of ethephon on the fruit when applied at different stages of fruit development.

Materials and Methods

Fourteen-year-old 'Giarraffa' olive trees (a typical cultivar of warm climates), located in a cool region of Central Italy, were selected for these experiments. Those trees were considered appropriate because in that area their fruits often do not ripen before winter, resulting in irreparable damage. The trees had 4 principal branches. Ethephon [active ingredient 48% as (2-chloroethyl)phosphonic acid] at 1000, 1500, and 2000 ppm with 100 ppm "Tensol" as the wetting agent, was applied to runoff on 4 trees each on September 21, October 23, and November 7, respectively, 30, 62, and 81 days after pit hardening began. Earlier periods were not included to avoid premature abscission of fruits. The control branches were sprayed with water and wetting agent, whereas the remaining 3 branches on each tree were given ethephon treatments. The treatment on each branch was repeated 4 times on the application date.

About the first week of November, pigmentation began on fruits treated with ethephon on September 21. Thus, 220 olives were taken for analysis on November 7, 16, and 24 from branches treated on September 21. Four samples of 25 drupes each were used for pulp dry weight determination, and another 100 fruits were used for caliper and pulp/stone ratio determination. The pulps from these latter samples were homogenized with distilled water and then freeze-dried for various analyses (Fig. 1). The remaining 20 fruits were used for determination of respiration rate and ethylene production. From September 5 to November 16, at about 10-day intervals, the respiration rate was measured also on fruit samples collected from untreated trees.

The respiration rate and ethylene production of whole fruits were determined as follows: 2 replicates of 10 fruits each, 5 hours after collection, were put in 250 ml Erlenmeyer vacuum flasks equipped with a gas-tight syringe on a sidearm and placed at 23°C in darkness. After 2, 4, 8, 12, 16, and 20 hr, 1.5 ml of air was injected into a gas chromatograph (Fractovap G. T. 200) with Hot Wire Detector (H. W. D.) and Flame Ionization Detector (F. I. D.), equipped with 3 columns: A) activated silica gel (CO_2); B) 5A molecular sieves (O_2), and C) activated alumina (ethylene). The A and B columns were connected to the H. W. D. and in order to eliminate the N_2 signal in B, the same N_2 was utilized as a transport gas, lowering the filament temperature. The system sensitivity was 0.5% for CO_2 and 1% for O_2 (v/v). The C column was connected to the F. I. D. with a nitrogen flow of 40 cc/min instead of the 70 cc/min used in H. W. D. The GC temperatures were 130° in the injector and detector and 70° in the column oven. The ethylene detection limit was 0.1 μl. The system enabled the discontinuous respiration measurement, which was reported in ml CO_2 produced or O_2 consumed by 1 drupe in 1 hr, to be taken. Respiration rate was extrapolated at the time of harvesting by means of negative exponential regression of the 6 determinations.

The detachment force at the final harvest on November 24 was measured on 100 fruit samples in each treatment. The harvested fruits were classified into 4 groups according to the color of the epidermis and mesocarp: (a) green; (b) partially darkened (c) totally darkened (black epicarp, green mesocarp); and (d) mature (black epicarp, partially pigmented mesocarp).

Results and Discussion

Only the September 21 ethephon treatment caused early fruit pigmentation, proportional to the concentration used. At final harvest, 91% of the fruit treated with 2000 ppm ethephon were in maturity classes "c" and "d", while only 39% of the control were in these classes (Fig. 2). The anthocyanin contents were significantly increased by ethephon treatment, particularly 1500 and 2000 ppm (Table 1). The absorption spectrum of the

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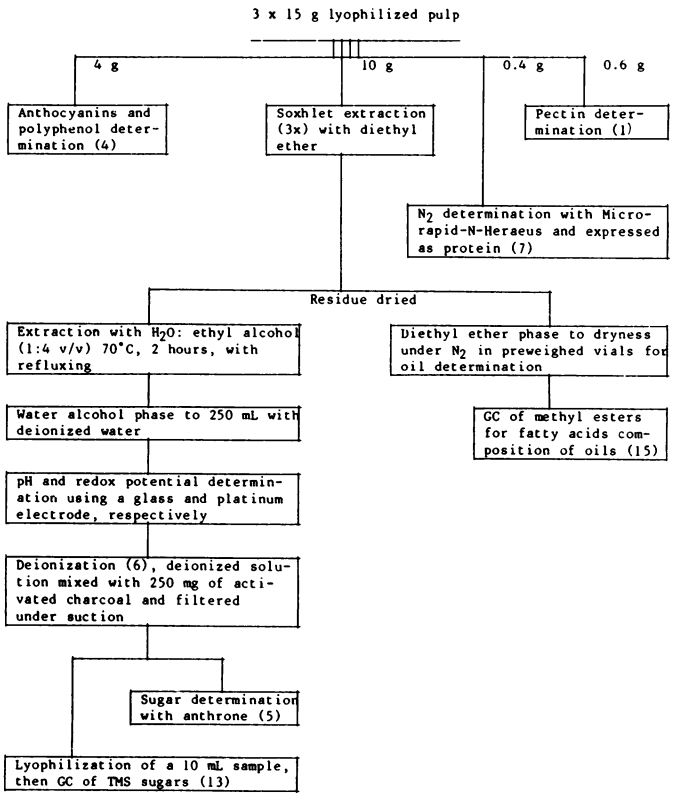

Fig. 1. Outline of analytical procedures.

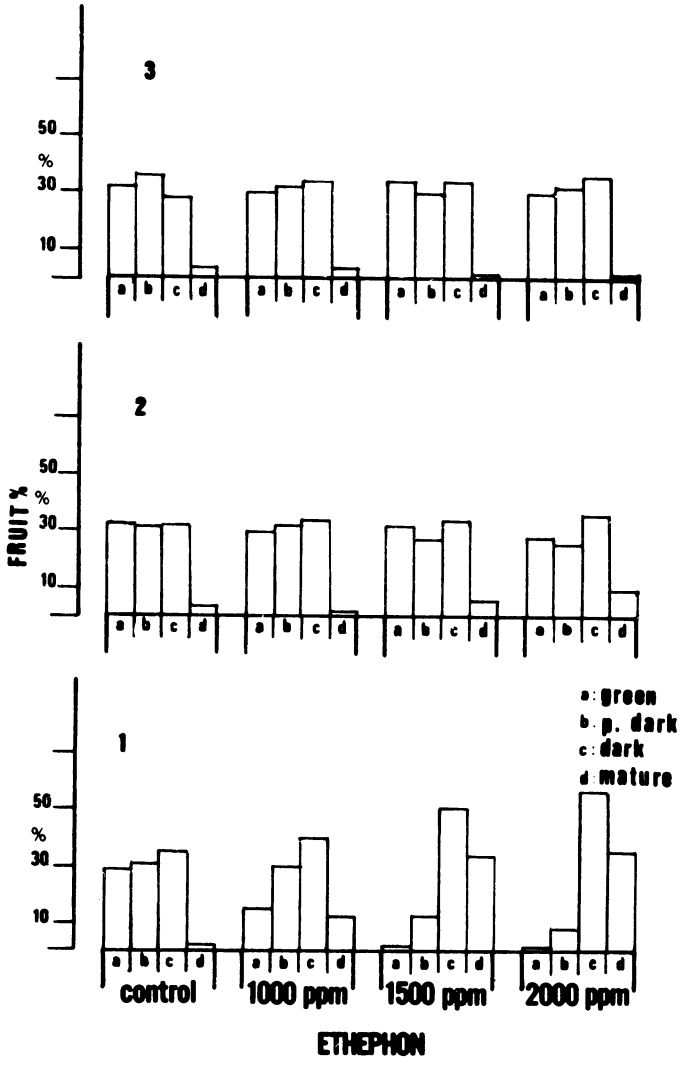

Fig. 2. Effects of ethephon concentration and treatment date (1 = September 21, 2 = October 23, 3 = November 7) on fruit pigmentation (a = green, b = epicarp partially darkened, c = epicarp darkened, d = mature) at final harvest (November 24).

extract, chromatographed on TLC, showed that its principal component was a cyanidin with maximum absorption at 533 nm.

Treatment with ethephon on October 23 or November 7 reduced the fruit detachment force at final harvest (Table 2). The pulp/stone volume ratio, length, diameter, and volume of the fruits were not affected by treatment. However, there was a slight increase in dry weight in the treated olives (Table 1). There was no significant effect of ethephon on pH, uronic acids, pectin, or protein contents of fruit (data not shown). Furthermore, no difference was found in total oil or in main fatty acid composition of fruits, but ethephon increased the linoleic/palmitoleic ratio (Table 3). However, the total polyphenol content was higher in 5 of 6 treated samples and at the third harvest date, olives treated with 1500 and 2000 ppm had a slightly higher redox potential than did controls (Table 1). The soluble sugars

Table 1. Significant effects of ethephon applied to olives on September 21 when fruits were harvested on November 7, 16, and 24.

Ethephon treatment (ppm)	November date	Pulp dry wt (% fresh wt)	Anthocyanins (Absorbance × 10^2)	Total polyphenols (g/100 g dry wt)	Redox potential (−mV)	Total soluble sugars (g/100 g dry wt)	Soluble sugars (% of total) Glucose	Fructose	Sucrose	Respiratory rate[y] (ml CO_2/ fruit hr^{-1})
0	7	---	0.27 f	---	---	---	---	---	---	0.6 b
	16	38.9 bc[z]	0.25 f	1.0 d	---	---	---	---	---	1.1 a
	24	39.3 bc	1.20 ef	0.8 d	455.0 d	8.0 A	54.4 A	38.0 A	7.6 A	0.3 c
1000	7	---	1.00 ef	---	---	---	---	---	---	0.7 b
	16	37.0 c	6.20 d	1.2 c	---	---	---	---	---	1.1 a
	24	39.3 bc	10.00 c	1.3 bc	454.0 a	8.7 A	59.5 A	34.1 A	6.4 A	0.3 c
1500	7	---	2.50 e	---	---	---	---	---	---	0.6 b
	16	39.1 bc	10.00 c	1.0 d	---	---	---	---	---	1.2 a
	24	41.1 b	10.70 c	1.3 bc	462.0 b	7.8 A	52.9 A	41.3 A	5.8 A	0.3 c
2000	7	---	2.00 b	---	---	---	---	---	---	0.7 b
	16	37.8 c	23.70 a	1.4 bc	---	---	---	---	---	1.1 a
	24	44.3 a	22.00 b	1.6 a	487.0 c	5.6 B	38.5 B	57.7 B	3.8 B	0.3 c

[z]ean separation in columns by Duncan's multiple range test, 5% level (lower case) or 1% level (upper case).
[y]eans of negative exponential regression extrapolated at harvesting time.

Table 2. Fruit detachment force (g) at final fruit harvest on November 24.

Ethephon (ppm)	Fruit detachment force (g) Treatment date Sept. 21	Oct. 23	Nov. 7
0	442 a[z]	445 a	405 ab
1000	453 a	458 a	402 ab
1500	427 a	407 ab	204 c
2000	438 a	338 b	152 c

[z]Mean separation by Duncan's multiple range test in columns and rows, 1% level.

content in fruits treated with 2000 ppm ethephon was significantly less than that of fruit in the other treatments, and the composition of sugars in fruit from this treatment was modified substantially, since they contained less glucose and sucrose and more fructose than fruit from the other treatments (Table 1).

No significant difference in respiratory rate between detached fruits from treated and untreated branches was measured, but considerable difference was noted among samples taken on different dates (Table 1) and it decreased quickly after detachment (Fig. 3). The respiratory ratios in the first and second harvest did not vary between treated and untreated samples. At the 3rd harvest (November 24), however, the fruits that had been treated with 2000 ppm ethephon showed a respiratory ratio notably higher than that of the control (Fig. 4). Ethylene emission was never observed (data not shown). The respiratory rate, measured on fruits harvested from untreated trees from September 5 to November 16, showed a maximum peak on October 14 (Fig. 5).

The ethephon treatments had a marked effect on olive ripening only when they were applied before the occurrence of the maximum respiratory rate; therefore, it may be assumed that the maximum rate observed has climacteric characteristics (Fig. 5). This respiratory dependence explains why ethylene-releasing chemical treatments, generally applied on olive trees during the preharvesting period to reduce the fruit detachment force, do not noticeably affect fruit ripening. Moreover, observations made on the detached fruits do not conform to the climacteric characteristics (10). In fact, their respiratory rate decreased rather quickly (Fig. 3) as compared to that of nonclimacteric fruits (11). Collectively, these results appear to support the hypothesis of Maxie et al. (10) which attributes a climacteric model to the attached olives and a nonclimacteric model to the detached ones.

The effects of ethephon on soluble sugars, linoleic/palmitoleic acid ratio, pulp dry weight, and respiratory ratio are very similar to the changes normally observed in olives during their last stage of natural maturation (7, 8). This indicates that ethephon applied

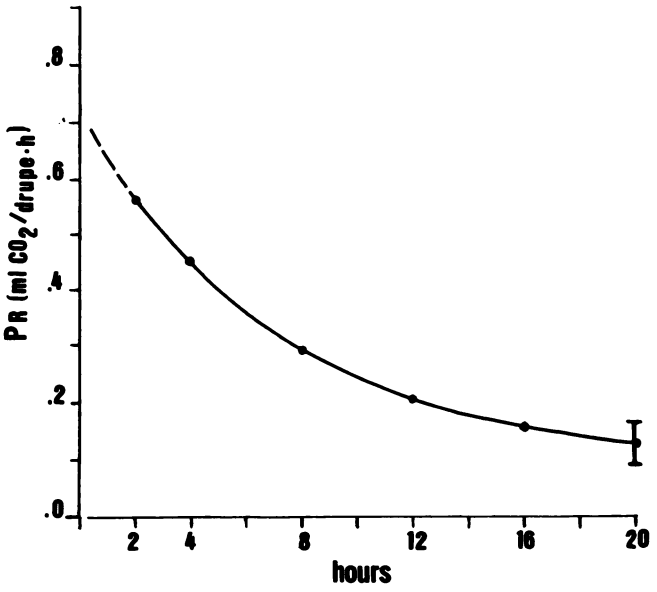

Fig. 3. A representative respiratory rate curve obtained using the data on November 7. Dashed line indicated extrapolation of PR (dark respiration) at the time of harvesting.

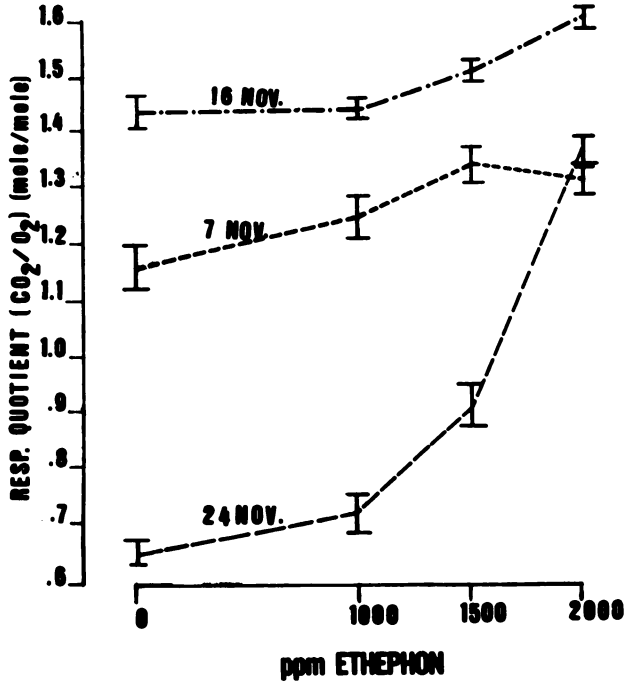

Fig. 4. Respiratory ratios measured on November 7, 16, and 24 on olives treated with ethephon on September 21.

Table 3. Oil content and fatty acid compositions in pulps of fruit treated on September 21 and harvested on November 24.

Ethephon (mg/liter)	Total oil (g/100 g dry wt)	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linoleic + eicosanoic acids (%)	Linoleic/ palmitoleic ratio
0	59.6	9.8	2.0	79.1	7.8	1.3	11.4 a[z]
1000	55.3	9.6	3.7	75.0	9.6	2.7	14.7 b
1500	60.0	9.5	2.5	78.3	8.7	1.0	14.6 b
2000	61.5	10.7	2.6	77.9	7.9	0.9	14.0 b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

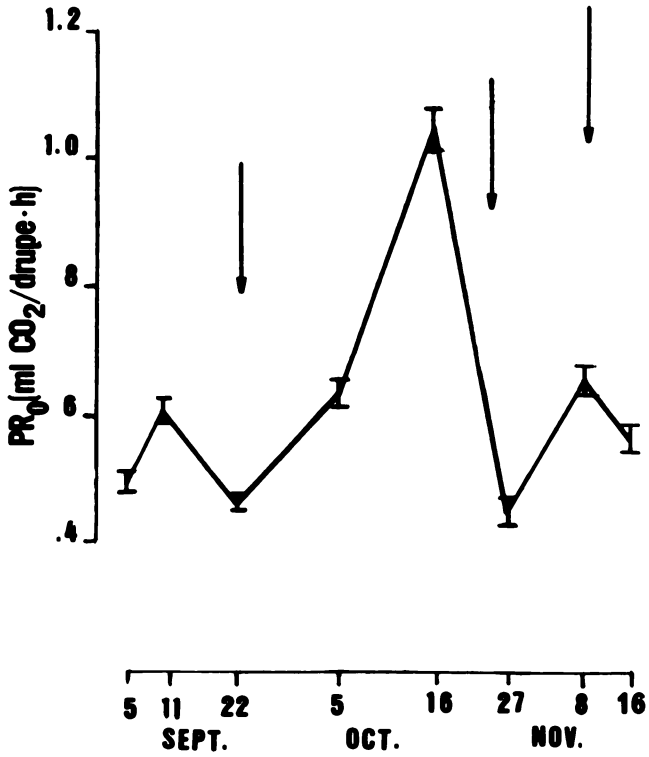

Fig. 5. Fruit respiratory rate, extrapolated at harvesting time on untreated plants. Arrows indicate the ethephon treatment dates.

prior to the maximum respiratory rate caused earlier ripening of the olives. Practically, this means that ethephon may offer considerable advantage in bringing about the early ripening of olives in trees situated in cold areas where their fruits do not normally ripen before the onset of cold weather.

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