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Improved Methods for Breaking Rest in the Peach and Other Deciduous Fruit Species[1]

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Abstract. The rest period of peach buds was broken by application of several compounds. DNOC-mineral oil, thiourea, aqueous DNOC, KNO_3, gibberellic acid and kinetin were found to be active. Combinations of active compounds found to be most efficient were: DNOC-mineral oil + thiourea; DNOC-mineral oil + gibberellic acid; and KNO_3 + thiourea. Potassium nitrate and kinetin mainly advanced flower bud opening, while thiourea had a more pronounced effect on leaf bud opening. Combinations of pairs of the 3 compounds, DNOC-mineral oil, thiourea and KNO_3 were best for commercial use.

Breaking the rest period of dormant organs has been a common practice since the beginning of this century. Of the many known rest-breaking agents (8) only a few have been found suitable for commercial use in deciduous fruit orchards. A winter spray with mineral oil emulsion fortified by DNOC is being used in Israel (11) and other warm countries (5) to overcome residual dormancy. Uncouplers of phosphorylation were found to break rest in peach buds (15). Thiourea, listed by Vegis (13) as among the most effective rest-breaking agents, was developed into a commercial spray for peach orchards by Blommaert (2, 3), who claims superior results in subsequent bud opening to those obtained by winter mineral oil sprays.

Among growth regulators, gibberellin was the most effective in breaking the rest period in peaches (7, 14). The effect of cytokinins is much less pronounced. Chvojka et al. (6) and Pieniazek (9) reported positive results with apples and Weinberger (16) with peaches. There is no clear-cut evidence that auxins break dormancy of buds on deciduous woody plants. Mineral salts have also been found to be active in relieving the rest in dormant organs; nitrate and sulfate salts are the outstanding ones of this group of compounds (8).

Since the results obtained with the commercially used mineral oil-DNOC spray were not always satisfactory, it was judged desirable to test other rest-breaking agents. The usefulness of these compounds alone and in combination was tested in an orchard after preliminary trials under controlled conditions. The peach was the principal species examined.

Materials and Methods

The laboratory experiments were performed on either one year old dormant potted plants, or on mature dormant excised shoots taken from fruit-bearing trees in the orchard. The latter were chosen at length of 50-60 cm and shortened distally to 40 cm. The terminal cut was rinsed in tap water for one hour. The shoots were then placed in beakers with their basal ends submerged in water after renewal of the proximal cut. The substances to be tested were applied either by spray, or through a latex tubing attached to the top of the excised shoots. Six whole plants or 12 to 20 excised shoots were used per treatment. The rate of bud opening was expressed as the percentage of buds which opened out of the total number present after a forcing period at 23°C in the light.

In the field experiments, the spray treatments were applied to entire mature fruit-bearing trees or to sectors thereof. The sprayer employed was either a "Lehavot" knapsack operated by CO_2 pressure (2½-3 atm), supplying a volume of ca. 600 liters per hectare, or a commercial gun sprayer with a pressure of 15 atm., supplying ca. 1000 liters per hectare. The surfactant "Triton X-100" was added to the aqueous solutions at 0.02%.

Bud opening was determined according to 2 categories: rate of bud opening evaluated in 11 steps corresponding to 0 to 100%; the relative development of those buds that were in the process of opening 5. Most of the field trials consisted of 6 randomly chosen replicates of entire single trees or of individual scaffold branch sectors.

The chemicals tested were: (a) the potassium salt of gibberellic acid (GA, "Berelex" I.C.I.), (b) kinetin (KIN) and (c) indoleacetic acid (IAA, Mann Research Lab.), which was dissolved in NaOH and pH readjusted to 8.0; (d) thiourea (TU) (Mallincrodt); (e) dinitro-ortho-cresol (DNOC), either as its sodium salt (prepared by slow heating of the compound in 2N NaOH) or as the ammonium salt in the commercial product "Super Elgatol"" (produced by Tapazol, Israel); (f) mineral oil "winter wash" (WW) consisting of either the Paz product "Universol" or the Tarsis product "Parlatox", both of which contain 1.5% DNOC. These oils are medium heavy, with a UR of about 75, emulsified with 20% water. (g) Potassium nitrate of technical grade (Haifa Chemicals, Israel).

Results

The rate of bud opening following the application of growth-promoting substances to small dormant 'Redhaven' peach trees in the laboratory is shown in Table 1. Gibberellic acid and kinetin increased the terminal bud opening by similar rates, but because of the great variability of the GA-treated plants, only the difference obtained by kinetin was significant. With lateral buds, the only significant enhancing effect was obtained with GA.

Table 1. The effect of growth-regulating substances at 200 ppm on leaf bud opening of potted one-year-old 'Redhaven' peach plants. (Sprayed on Feb. 23, 1964 and forced from Feb. 23 to March 25, at 23°C, in continuous light at 710 lux at mean plant height; ± S. E.)

Treatment	Bud opening	
	Terminal	Lateral
Control	53.0 ± 3.7	13.8 ± 5.9
IAA	63.3 ± 11.7	23.8 ± 1.3
GA	75.6 ± 12.4	45.4 ± 3.1
Kinetin	77.0 ± 6.4	27.0 ± 3.9

These results suggested that the effect of gibberellic acid in combination with other growth regulators should be examined. This was carried out on excised unchilled 'Elberta' peach shoots.

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[2]Erez, A. 1968. Effects of exogenous and endogenous factors on fruit tree dormancy. Ph.D. Thesis. Hebrew University of Jerusalem, Israel (in Hebrew).

Table 2. The effect of growth-regulating substances and thiourea on leaf bud opening of dormant excised 'Elberta' peach shoots collected and treated on Jan. 1, 1965. Data recorded after 24 forcing days at 23°C in light; concentration in ppm.

Substance added	Bud opening (%)								
		GA		IAA		Kin.		TU	L.S.D.
	Control	100	500	100	500	100	500	$1x10^4$	(P=0.05)
—	0.0	3.7	9.1	0.0	0.0	3.6	2.6	10.6	5.3
GA 100		—	—	5.8	1.3	7.1	7.0	17.3	4.6
L.S.D. (P = 0.05)				5.0	N.S.	N.S.	3.0	4.6	

The results of a typical experiment are shown in Table 2. The best results with a single substance were obtained by the application of 1.10^4 ppm thiourea or 500 ppm GA. The addition of 100 ppm GA, however, to the various substances and concentrations produced an additive effect. The best stimulation of bud opening was obtained with the combination of GA and thiourea.

The treatments applied under controlled conditions were subsequently tested in the orchard in 1965. Trees with well-developed scaffold branches ('July-Elberta') were selected and treated with either GA, kinetin or thiourea, and compared with the commercial DNOC mineral oil spray ("Parlatox" winter wash). Rate of leaf and flower bud opening, expressed both as level of open buds and the stage of their development on a certain date, are given in Table 3.

Table 3. The effect of dormancy-breaking agents on the bud opening on sectors of 'July-Elberta' peach trees sprayed on Feb. 24, 1965. Bud opening evaluated on March 24 at Gilat, northern Negev.

Treat.	Concn. (%)	Leaf buds		Flower buds	
		Stage (0 - 4[X])	Opening (percent)	Stage (0 - 4[X])	Opening (percent)
Control		0.5	7	0.7	47
W.W.	4.0	0.6	13	0.4	42
GA	0.02	0.7	17	1.0	50
Kin.	0.02	0.9	13	1.0	64
TU	0.2	1.0	15	1.2	72
TU	2.0	1.7	32	1.2	62
TU + GA	0.5 + 0.02	0.5	22	1.1	69
W.W. + GA	4.0 + 0.02	0.7	27	1.2	64
L.S.D. (P = 0.05)			N.S.		21

[X]Stage 0 = least developed; stage 4 = most developed.

Leaf bud opening was enhanced by all treatments, but particularly by 2% thiourea and the combination G.A.-winter wash. Rate of opening of flower buds was increased by 0.2% thiourea and the combination of 0.5% thiourea and gibberellic acid.

In 1966 the 3 dormancy-breaking agents, thiourea, gibberellic acid and dinitrocresol, alone and in combination, were tested. Entire mature 'Robin' peach trees were sprayed 5 weeks prior to expected bud swelling, in an orchard at Rosh Ha'Ayin (central coastal plain) and another one at Tel-Adashim (Yizre'el valley). The rate of bud opening is reported in Table 4.

Thiourea at 2% was the most active. All 3 combinations appear to increase the rate of bud opening. The combination of gibberellic acid and thiourea acted additively, while gibberellic acid or thiourea, in combination with dinitrocresol, deomnstrated synergistic effects on the opening of leaf buds. The efficiency of the 3 combinations was similar at both locations. Therefore, the relatively expensive treatment with GA was omitted in the next trials.

Results obtained in the next 2 years in one 'Robin' peach orchard at Nir Banim (southern coastal plain) are summarized in Table 5. The first winter (1966/67) was cooler than the following one, therefore bud opening was better in the first than in the second year. The combination of "winter-wash" and TU produced the best results for rate of opening of both bud types in 1967, and of leaf buds in 1968. Flower bud development was much advanced by this treatment in 1967 (Fig. 1). Separate, successive applications of the 2 substances when the winter wash follows the aqueous TU spray, was superior to a single mixed application. Early spray with thiourea (6 weeks prior to start of bud swelling) enhanced bud opening, but flowering and leafing out were less uniform than when the spray was applied at a later date (4 weeks prior to bud swelling).

The action of thiourea was most pronounced with leaf buds, while KNO_3 mainly influenced flower buds. A combination of the 2 compounds had the most pronounced effect on rate and uniformity of leaf and flower bud opening.

The effect of thiourea and "winter wash" was also tested on other deciduous fruit species and the evaluation of bud opening following treatments is shown in Table 6. Significantly better bud opening was obtained with all 3 Rosaceae species by the combination of thiourea and "winter wash" than the control or with each agent separately. With apricots, however, the combined treatment did not significantly increase flower bud opening over either separate treatment. Thiourea enhanced bud opening of the 'Perlette' vine and similar results were obtained with other grape cultivars (e.g. 'Alphonse Lavallee', 'Thompson Seedless') in various regions of Israel during 1966/7 and 1967/8. No oil treatment was given to the vine, because a previous negative effect on grape buds was observed (unpublished data).

Discussion

A number of substances known to be active in breaking dormancy were tested on the peach in order to increase bud break under conditions of prolonged dormancy. While IAA did not break dormancy, both kinetin and gibberellic acid were effective in both the laboratory and the orchard. In addition, thiourea, KNO_3, and dinitro-ortho-cresol in aqueous solution and in oil emulsion, were rest-breaking agents for the peach. Some of these substances affected leaf buds more than flower buds, and some vice versa (thiourea belongs in the first category and KNO_3 and kinetin in the second). The effect of thiourea was first demonstrated in peach by Blommaert (3), and exists in other species also.

The reason for the differential effect of the substances on leaf and flower buds is obscure, since knowledge of the physiology of dormancy in the 2 types of buds is limited. The favorable effect of KNO_3, especially on flower bud opening, might be explained on the basis of the poorer transport system leading to the flower bud in the peach and the dependency of nitrate reductase induction on NO_3^- (1). A low level of nitrate reductase during the prebloom period, resulting from a shortage of NO_3^- might become a limiting factor in flower bud development. Such a hypothesis is strengthened by recent findings (10) that both gibberellic acid and kinetin strongly increased nitrate reductase activity.

Two of the most potent rest-breaking agents in the peach, thiourea and nitrate, are known to be effective in promoting germination of dormant seeds (12). This fact indicates that these agents have an effect on the basic mechanisms of dormant organs.

The application of any 2 substances together, or in close

Table 4. The effects of dormancy-breaking agents on percentage of the bud opening on whole 'Robin' peach trees. (Sprayed on Feb. 25, 1966 at Rosh Ha'ayin and on Feb. 27 at Tel Adashim, and examined on April 3 and March 27 respectively).

Treat.	Concn (%)	Rosh Ha'ayin		Tel Adashim	
		Leaf buds	Flower buds	Leaf buds	Flower buds
Control		0	15	0	17
DNOC	0.2	1	42	—	—
GA	0.02	9	41	—	—
TU	1.0	4	40	—	—
TU	2.0	10	57	8	40
GA + DNOC	0.02 + 0.2	23	71	2	51
GA + TU	0.02 + 1.0	17	67	10	55
DNOC + TU	0.2 + 1.0	15	70	4	55
L.S.D. (P = 0.05)		6.5	8.0	6.3	16.5

Table 5. The effect of dormancy-breaking agents on the percentage of open buds on 'Robin' peach trees sprayed on Feb. 20, 1967 and Feb. 15, 1968. Evaluated on April 5 and March 18, respectively, at Nir Banim.

Treat.	Concn (%)	1967		1968	
		Leaf buds	Flower buds	Leaf buds	Flower buds
Control		0	47	0	31
W.W.	5.0	15	66	15	58
DNOC	0.2	0	47	—	—
TU	2.0 (Early)[a]	—[b]	—	47	56
TU	2.0	5	38	45	54
TU + W.W.	2.0 + 5.0 separate[c]	30	84	67	58
TU + W.W.	2.0 + 5.0 combined	20	75	—	—
TU + DNOC	2.0 + 0.2	5	69	—	—
KNO_3	2.0	—	—	0	43
KNO_3	5.0	—	—	0	71
KNO_3 + TU	2.0 + 2.0	—	—	52	85
L.S.D. (P = 0.05)		6.3	18.5	12.7	13.7

[a]Sprayed 2 weeks earlier than the reported date.

[b]Treatments not applied this year.

[c]TU sprayed first.

Table 6. The effect of thiourea and mineral oil-DNOC emulsion, separately and in combination, on the bud opening of 4 deciduous fruit species. Bud development for Rosaceae was judged by 5 stages described in Table 3; for the grapevine, it was judged as average length of the young shoots, in cm.

Species and Variety	Treatment date	Examination date	Bud type	Bud development				
				Control	5% W.W.	2% TU	2% TU + 5% WW	L.S.D. (P = 0.05)
Japanese plum (Santa Rosa)	Jan. 25	March 12	Leaf	2.0	2.2	2.1*	2.9*	0.5
			Flower	2.2	2.4	2.6*	3.3*	0.6
Apricot (Canino)	Feb. 4	March 18	Leaf	1.4	2.3	2.4	3.4	0.8
			Flower	2.1	3.6	3.9	3.9	0.3
Apple (Golden Delicious)	Feb. 22; March 29	April 9	Mixed	1.3	2.1	2.8	3.4	0.8
Grapevine (Perlette)	Jan. 11	March 12		7.2	—	12.2	—	2.2

*Thiourea concn = 1%

succession on the same plant, increased the effect above that of each substance alone. While the effect of thiourea seems to be additive to that of gibberellic acid, the combination of thiourea with dinitro-cresol, "winter wash", or KNO_3, and of dinitrocresol with gibberellic acid, seems to be synergistic. The effect of different groups of substances indicates that different systems leading to bud opening are influenced simultaneously. This conclusion is supported by the observation that dinitrocresol and "winter wash" strongly increase the respiration rate, while gibberellic acid and thiourea slightly reduce it[2](4).

The application of these combined treatments in the orchard are more effective than the 2 treatments presently in use, namely DNOC-mineral oil (5, 12) and to a lesser extent, thiourea (3). The effectiveness of the DNOC-mineral oil treatment is dependent on prevailing temperatures during the few days following treatment. Increased activity occurs with increasing temperatures, up to the point of phytotoxicity. Since

Fig. 1. Bud opening on 'Robin' peach trees. Left: untreated. Right: Trees sprayed on February 20, 1967, with a combination of 5% W. W. and 2% T. U. (Photographs taken on April 5, 1967 at Nir Banim.)

the effect of the treatment is dependent upon an unknown factor, results can not be accurately predicted. Thiourea, on the other hand, can damage flower buds, especially on weak trees, and different sensitivity to the compound may exist among species and cultivars. Blommaert (2) warned against spraying with thiourea closer than 2 weeks prior to the expected start of bud opening. We found that a safety range of 4 or even 5 weeks is essential in order to prevent injury to flower buds. There are indications that a concentration of 2% thiourea might be too high. An increase in the volume applied per tree will increase the risk; a fact which points to a rapid absorption of thiourea. We thus recommend a rate not to exceed 10 kg of thiourea per hectare.

A combination of mineral oil, or DNOC in aqueous solutions in oil-sensitive peach cultivars with thiourea, has recently given excellent results in commercial application to peach, Japanese plum, apple and pear orchards. The addition of KNO_3 increased the amount of open blossoms and, as a result, the number of fruits per tree (unpublished data). By choosing the right combination of substances it seems possible either to increase (adding KNO_3) or to decrease (proper timing of thiourea, resulting in flower bud thinning) the level of flowering in stone fruit species. Moreover, the powerful combination of "winter wash" and thiourea enables relatively early application, with the result of advanced flowering (without a loss in yield) and hence early fruit maturation.

It should be noted that when combined treatments include an oil spray, the aqueous solutions must be applied before the oil spray, or the oily film will interfere with penetration.

The proper time of application of KNO_3 and thiourea in relation to the winter wash treatment is still not clear, and is presently under study.

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