AN ABSTRACT OF THE THESIS OF

Margaret Dorothy Collins for the degree of Master of Science
in Horticulture presented on March 17, 1977

Title: DELAY OF ANTHESIS IN 'BARTLETT' AND 'BOSC' PEARS (PYRUS COMMUNIS) BY EVAPORATIVE COOLING

Abstract approved: ______________________
Porter B. Lombard

The influence of evaporative cooling for delay of 'Bartlett' and 'Bosc' fruit bud development for frost avoidance was investigated. Two mist systems, one in a mature pear orchard and the other in a young pear hedgerow, delayed 'Bartlett' and 'Bosc' bloom up to 15 and 8 days respectively. A low pressure sprinkler system delayed 'Bartlett' bloom 14 days and 'Bosc' bloom 8 days. Bloom delay resulted in increased set, seed count, and fruit growth rates. Return bloom was reduced in the mature orchard 'Bartlett' mist and 'Bosc' sprinkler plots in 1976 and this resulted in reduced cropping the following year. Fruit sizes were reduced 6% for 'Bartlett' and 12% for 'Bosc' while harvest maturity was delayed 0 to 6 days and 2 to 7 days respectively. Soluble solids were lowered in the misted hedgerow. Titratable acid was not affected by the bud development delay. Foliar N levels were reduced in the water treated plots. Pear psylla activity was delayed by misting while fire blight produced 36 strikes in 1976.

Delay of Anthesis in 'Bartlett' and 'Bosc' Pears (*Pyrus communis*) by Evaporative Cooling

by

Margaret Dorothy Collins

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1977

APPROVED:

Professor of Horticulture

in charge of major

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Date thesis is presented March 17, 1977

Typed by Clover Redfern for Margaret Dorothy Collins

Note: This thesis is presented in the form of two papers to be submitted to the Journal of the American Society for Horticultural Science. The format of these papers corresponds to that required by this journal.

Knowledge is like a circle. The more we
learn, the greater we are aware
of the increasing perimeter of ignorance.

Anonymous

If a man has two pennies, he should buy
a loaf of bread with one - which will sustain
his life -
and a flower with the other - which will give
him a reason to live.

Chinese Proverb

ACKNOWLEDGMENTS

I would like to extend thanks to Dr. John Wolfe for the patience and consideration he showed during my academic program and to Dr. Porter Lombard for functioning as my advisor, keeping the Medford project operative, and providing the necessary insights for the writing of this thesis.

I would also like to extend special thanks to Dr. Daryl Richardson for his continuous moral support and assistance over the past two years.

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LITERATURE REVIEW

Frost injury reduces fruit cropping and value, and produces losses to processing, packing, and marketing aspects of fruit production. Cost of frost protection may actually be greater than the value of the crop.

Various methods have been used to protect tree fruits from losses occurring as a result of low temperatures due to spring frosts. Of the methods to protect against frost injury, orchard heating with diesel fuel burners is the most common. Unfortunately, heating is inefficient (Gerber 1970), costly, and environmentally unfavorable.

Overtree sprinkling of fruit trees to produce continuous icing around the fruit bud has also been used. In this procedure, latent heat of fusion is released when water turns to ice, resulting in increased temperatures. However, Gerber and Harrison (1964) report that breakage may occur to mature citrus trees due to ice loading or use of insufficient water may accentuate freeze damage under windy conditions.

Overtree wind machines, which mix the heat stored in the air with cooler air masses to increase temperatures, depend on temperature inversions or gradients to be effective. Little or no protection is possible if the necessary temperature inversions are weak or infrequent (Gerber 1970).

Cold water fog generation to prevent loss of heat energy was shown by Brewer et al. (1974) to protect citrus during January and February, but only when wind speeds were low. Adequate fog of an effective droplet size and coverage for protection was difficult to produce.

Ketchie and Murren (1976) found that cryoprotectants increase cold resistance of shoots and bark of apple and pear trees. Cultivars differed in reaction to the cryoprotectants investigated.

The major methods of frost protection are utilized following the dormancy period of the trees, when fruit buds are in various developmental and frost susceptible stages.

Recently, a method of frost avoidance by bloom delay was investigated (Alfaro et al. 1974) (Anderson et al. 1975). Fruit bud development was delayed by evaporative cooling in early spring. Evaporative cooling has successfully reduced many crop temperatures. Miller et al. (1963) reported air temperature reductions of 3-5°C in an avocado orchard with overhead sprinkling. Van Den Brink and Carolus (1964) sprayed tomatoes in the field and reduced air temperatures in the plant canopy 10-12°C during low humidity. Misting snap beans (Wheaton and Kidder 1966) resulted in lower plant temperatures and higher yields. Lombard et al. (1966) used low volume overtree sprinkling to reduce fruit temperatures 4-6°C in a pear orchard. They found that cooling by sprinkling also lowered air temperatures, increased humidity, and resulted in higher fruit growth rates and earlier maturation for 'Bartlett' pears. Gilbert et al. (1970) lowered air, leaf, and grape berry temperatures while increasing humidity by using over-vine sprinkling. They stated that fruit quality, measured by sugar/acid ratio, pH, and total acidity, tends to be better with some grape varieties when the crop is cooled. A reduction in plum temperatures by spray irrigation has also been reported (Gay et al. 1971). In a detailed study on the effects of low volume overtree sprinkling on 'Red Delicious' apples, it was found that evaporative cooling reduced air and fruit temperatures (Unrath 1972 a), improved fruit color (Unrath 1972 b), increased soluble solids and fruit weight (Unrath and Sneed 1974), accelerated fruit maturity (Unrath 1973), and reduced some physiological disorders (Unrath and Sneed 1974).

From these investigations, it appears that evaporative cooling could be used to cool fruit buds and thus delay flowering.

Deciduous fruit trees will not grow during a "rest" period in the winter, even if there are favorable environmental growing conditions (Hatch and Walker 1969) (Proebsting 1963). Until rest is completed, fruit buds are tolerant to low temperatures. The minimum temperature hardiness is dependent upon growing conditions the previous season, fruit type, cultivar, and dehardening occurring as a result of warm temperatures during the rest period (Proebsting 1970). Chilling temperatures, with an optimum of 7.2°C are normally required to break rest in fruit buds by activating biochemical components and triggering the growth mechanism (Walker 1970). As warmer weather occurs when rest is completed, growth is resumed and cold hardiness is lost at temperatures above -2°C (Proebsting and Mills 1961) (Proebsting 1970). Low temperatures of -5 to -2°C during bud developmental stages can result in damage and death of the buds to produce crop losses (Proebsting 1963).

By delaying fruit bud development, particularly in an early season, frost damage might be reduced. Richardson et al. (1974) have developed a model based on computer synthesized hourly temperatures, calculated from daily minimum and maximum temperatures, to predict the time of rest completion. Hourly temperatures between 1.5 to 18°C are converted to positive or negative chill-units and accumulated throughout the winter. When the chill-unit requirement, which differs with cultivars, is met, evaporative cooling should be initiated for frost protection.

Alfaro et al. (1974) sprinkled apple and cherry buds with a two minute on-off cycle at air temperatures above 7°C after rest. Bud temperatures were reduced a maximum of 34.5°C which resulted in a bloom delay of 17 days for apple and 15 days for cherry. Apple maturity, measured by % soluble solids, was delayed approximately one week. Anderson et al. (1975) reported in the same study that calcium carbonate deposited on the sprinkled trees resulted in lower bark and bud temperatures, but that no differences in size or color of the delayed apples were noted.

Bauer et al. (1976) observed that 'Redhaven' peach buds, sprinkled when bud temperatures exceeded 4.4°C, were bloom-delayed 15 days. Wood temperatures were reduced by 6.5°C during sprinkling. No differences in fruit sugar or fruit protein levels were noted, but yields were lower in the sprinkled trees. Cooled fruit buds were hardier than non-cooled buds until March 31, then the bud hardiness was reversed. The authors hypothesize that the large amount of water applied by sprinkling may have weakened the buds on the trees. Barfield et al. (1976) further reported on a sprinkling system which responds to evaporative demand to reduce the amount of water applied to the buds.

Low pressure misting of 'Golden Delicious' apple trees in Ohio delayed bloom, but greatly increased the incidence of fire blight (Spotts et al. 1976).

Wolfe et al. (1976) studied evaporative cooling for bloom delay on 'Bartlett' and 'Bosc' pear trees by comparing a mist and a low pressure sprinkler system. Bud temperature depressions for the mist and sprinkler systems were 5°C and 2.8°C respectively. The systems were activated when air temperatures reached 7.2°C. The mist systems used less water and resulted in longer bloom delay than did the sprinkler system for both cultivars.

Bloom delay by evaporative cooling for frost avoidance is a possible alternative to methods now used for frost protection. However, the effects of the cooling and bloom delay on fruit and tree parameters such as fruit set, yield, maturity, quality, foliar mineral content, and pest incidence should be evaluated before recommending this practice.

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EFFECTS OF EVAPORATIVE COOLING FOR BLOOM DELAY ON 'BARTLETT' AND 'BOSC' PEAR TREE PERFORMANCE[1]

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Abstract. Two mist systems, one in a mature pear orchard and the other in a young pear hedgerow, delayed bloom 15 days for 'Bartlett' and 8 days for 'Bosc', while a low pressure sprinkler system delayed bloom 14 and 8 days for 'Bartlett' and 'Bosc', respectively, in 1976. Bloom delay generally increased fruit set and seed content of the fruit. Return bloom was greatly reduced in the mature orchard 'Bartlett' mist and 'Bosc' sprinkler plots in 1976 and, in turn, cropping was reduced the following year on these plots. Yield was generally lower in the treated areas. Fruit growth rates were

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[1]Received for publication ________________. Portions from a thesis presented to the Graduate School of Oregon State University by the senior author, in partial fulfillment of the requirements for the MS degree.

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[4]Collins, M. D., P. B. Lombard, and J. W. Wolfe. 1977. Effects of evaporative cooling for bloom delay on 'Bartlett' and 'Bosc' pear maturity and quality. Report to be submitted for publication. Amer. Soc. Hort. Sci.

accelerated in the bloom-delayed trees, but total fruit volume was less than the non-delayed fruit. Leaf nitrogen levels were reduced in all bud delayed treatments. Pear psylla oviposition was delayed in the mist system. Fire blight, absent in 1975, was found in the misted 'Bosc' and in the sprinkled plots of both cultivars in 1976.

Methods employed to protect tree fruits from frost damage include orchard heaters (4), overtree sprinklers (4), overtree wind machines (4), and cold water insulating fog (3). But recently, frost avoidance by bloom delay with microclimate modification by evaporative cooling has been promising for apple (1), cherry (1), and peach (2) trees. However, low pressure misting of 'Golden Delicious' apple trees in Ohio delayed bloom, but also increased the incidence of fire blight (8). Bloom delay by cooling must begin after the rest period has been completed, which led Richardson et al. (7) to propose a model for determining completion based on hourly temperatures between 1.4 and 18°C during the rest period. The completion requirement for pears is 1500 chilling units, which usually occurs about January 1 in Medford.

Early bud development of pears in southern Oregon has led to severe frost damage in 1968, 1970, and 1972. Therefore, frost avoidance by prebloom cooling to delay bud development could be a practical solution. Our objectives were: 1) to engineer a system for delaying fruit bud development of 'Bartlett' and 'Bosc' pears by evaporative cooling and 2) to determine the effects of bloom delay on fruit set, seed count, yield, growth rate, return bloom, foliar mineral content, and pest problems.

Materials and Methods

In 1974 a high pressure fogging system operating at 2 MPa (300 psi) was established in a 40 year old 'Bartlett' and 'Bosc' pear orchard with a 7.6 x 7.6 spacing in Medford, Oregon (10). Trees in this orchard are 4.9 m in height with a skirt diameter of about 5.5 m. The system contained peripheral fogging lines and interior lines on alternate tree rows with a 14.4 m spacing. Since mist coverage was not uniform, the system, with a reduced pressure of 1 PMa (150 psi), was redesigned in 1975 to eliminate the peripheral lines and distribute the nozzles at 1.5 m spacings in an area of 0.17 ha. Also established in 1975 was a mist system in a young hedgerow plot with a 3.8 m x 1.5 m spacing, and a low pressure (103 kPa, 15 psi) sprinkler system in the mature orchard (10). In 1976, pressure of the mist system in the mature orchard plot was reduced to 0.60 MPa (90 psi). The hedgerow mist system was enlarged to incorporate 120 trees on Calleryana (Call) and Naumes (Nau) rootstocks, and the same nozzle spacing (1.52 m) as the mature orchard (10). In the sprinkler plot, larger sprinklers with a higher application rate were cycled on and off every 2 1/2 min in 1976. All systems were operated after completion of rest in January until bloom in the control plot. In 1974, a base initiation temperature of 10°C was used, but this was changed to 7.0°C in 1975 and 1976 (10) (11).

Fruit set was determined from 50 fruit buds per quadrant of each tree and from a corresponding fruit count after June drop. Fruit growth rates were recorded for Bartletts in the sprinkler and control plots for 1976. Five fruits on 4 trees were measured at the largest circumference every third day from 36 days after full bloom until harvest. Growth rates were converted to the volume of a sphere. Seed counts were made on samples at harvest. Tree yields were recorded during harvest. Foliar analysis were performed on 50 leaves per tree in the mature Bartlett plots in 1975 and for both cultivars in all plots in 1976. Data were processed by analysis of variance and Duncan's multiple range test.

Results and Discussion

Since 'Bartlett' pear trees bloom earlier than 'Bosc', it is necessary to delay 'Bartletts' for a longer period of time in order to avoid frost. In Medford, the calculated delay should be at least 14 days for 'Bartlett' and 7 days for 'Bosc'. The bloom delay systems investigated met these requirements (Table 1). The systems were turned off when control plot 'Bartlett' was in full bloom. The 'Bosc' were not cooled in the last stages of pre-bloom, therefore, they were delayed less than the 'Bartletts'. The increase in bloom delay in 1976 resulted from the systems being run over a longer period of time (20% more hours). The mist system provided greater bloom delay and used less water per day of delay than did the sprinkler system (10) (11).

Fruit set has been shown to be temperature related, as low temperatures following bloom may reduce pollen tube growth and subsequent fruit set (6). Though set was generally higher in the delayed treatments, which might be expected due to the higher temperatures occurring later, it was only significantly higher for the misted 'Bartlett' and sprinkled 'Bsoc' in 1976 (Table 1), but this could be a reflection of the low bloom density (Table 2).

Seed counts were higher in the delayed bloom plots in 90% of all cases (Tables 1 and 3), probably due to more favorable temperatures (higher) for pollen tube growth after bloom (6). A treatment x cultivar interaction in the hedgerow showed that the delay in bloom had a greater influence on seed content of 'Bosc' than of 'Bartlett' (Table 3).

Fruit seeds may have an inhibiting effect on flower initiation in pears the following season (5). It was observed that bloom was reduced in some of the delayed plots, so flower density, flower no. / limb area (cm^2), was calculated in 1976. Bloom density was reduced in the misted 'Bartlett' and sprinkled 'Bosc' from 1975 (Table 2). The low bud initiation in sprinkled 'Bosc' probably resulted from high seed counts in 1975 (Table 1). Unfortunately, 'Bartlett' seed counts were not taken in 1975, but the low bud counts of misted trees in 1976 could be due to high seed counts the previous year. The failure of the sprinkler 1976 'Bartlett' to react in this way is probably due to low fruit load (Table 1), hence fewer seeds per tree in 1975.

Yield was reduced generally in the bloom-delayed plots, but significantly in only 27% of all cases (Table 1). A significant yield reduction the following year would be expected when bloom delay causes higher seed counts and subsequent lower bud initiation. The influence of bloom delay on yield in the hedgerow was greater on 'Bartlett' than 'Bosc' as noted in the treatment x cultivar interaction (Table 3). This cultivar effect could be due to fruit set differences of the two cultivars (Table 1).

Fruit growth rates, calculated in volume on sprinkled 'Bartlett' in 1976, showed fruit on bloom-delayed trees with a greater daily growth rate after the 95th day from bloom. However, the fruit volume at harvest in the sprinkled plot was less than in the control trees.[4]

Foliar analysis showed nitrogen levels to be consistently reduced in bloom-delayed plots. Since the water application is occurring before the trees are in leaf, N losses may be due to soil leaching or to anaerobic conditions produced by excess standing water. Though N levels were reduced, they were still within normal ranges, and no additional applications of N were necessary during the season.

Observations on pear psylla activity and egg laying, which were reduced during the cooling period, indicated misting cools the adult psylla and delays oviposition prior to bloom. It is possible that cooling could also delay other pest problems, such as San Jose scale development. There were no fire blight strikes in 1974 or 1975. However, in 1976, there were 0.7 strikes/tree of both cultivars in the sprinkler plot and 3 strikes/tree in 'Bosc' of the mature misted orchard. Fire blight strikes have been found several days after an 18.3°C mean temperature day during pear bloom (9). The first occurrence of this temperature in 1976 was on May 7 when 'Bosc' was in bloom and when 'Bartlett' was in post-bloom. This is considerably less fire blight than reported by Spotts et al. (8) who reported 6.3 strikes/tree in sprinkler bloom-delayed 'Golden Delicious' apples. Though fire blight has not been a problem in the years under study, a danger does exist that delaying bloom until mean temperatures are higher could accelerate incidence of infection. This would have to be a consideration for adopting this type of frost avoidance.

Bloom delay increased seed content and fruit set because of more favorable temperatures. Flower initiation and subsequent fruit yields were reduced in the bloom-delayed plots because of the higher seed contents. Fruit growth rates, accelerated in the bloom-delayed trees, did not result in larger fruit at harvest. Foliar N levels were lowered in the water treated plots. Pear psylla activity was delayed by misting while fire blight infected 36 limbs in 1976.

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Table 1. Effects of evaporative cooling on delay of bud development, fruit set, seed count, and yield of 'Bartlett' and 'Bosc' pears in 1975 and 1976.

Cultivar and Treatment	Delay in full bloom (days)		Fruit set/100 flower clusters		Seed count/fruit		Yield kg/tree	
	1975	1976	1975	1976	1975	1976	1975	1976
Mature orchard 'Bartlett'								
Mist	11	15	34c	295a	-	6.7a	163ab	105b
Sprinkler	7	14	58b	157b	-	5.7ab	132b	208a
Control	0	0	77a	130b	-	5.1b	180a	211a
Significance	-	-	5%	1%	-	5%	5%	1%
Hedgerow 'Bartlett'								
Mist	13	15	-	42	-	5.2	11	35a
Control	0	0	-	35	-	5.0	12	20b
Significance	-	-	-	N.S.	-	N.S.	N.S.	5%
Mature orchard 'Bosc'								
Mist	7	8	142	129b	4.3a	5.1ab	156	178
Sprinkler	6	8	88	185a	4.7a	6.6a	145	133
Control	0	0	98	123b	2.8b	3.7b	153	215
Significance	-	-	N.S.	5%	5%	1%	N.S.	N.S.
Hedgerow 'Bosc'								
Mist	-	8	-	66	-	5.1a	-	27
Control	0	0	-	62	-	3.7b	-	26
Significance	-	-	-	N.S.	-	5%	-	N.S.

Mean separation in columns by Duncan's Multiple Range Test at the indicated level.

Table 2. Effect of bloom delay in 1975 on flower density in 1976 of 'Bartlett' and 'Bosc' pear trees.

Cultivar	Flower density, 1976 (# flower buds/cm^2 limb area) 'Bartlett'	'Bosc'
Treatment 1975.		
Mature orchard		
Mist	.39	2.22
Sprinkler	2.27	.98
Control	1.60	1.93

Table 3. Effects of bloom delay on means and significant interactions of seed count and yield in hedgerow 'Bartlett' and 'Bosc' pear trees in 1976.

	Seed count (seeds/fruit)		Yield (kg/tree)	
	Rootstock		Rootstock	
Cultivar and treatment	Calleryana	Naumes	Calleryana	Naumes
Bartlett				
Mist	5.2	5.2	22.1	47.2a
Control	4.9	5.3	11.0	28.6b
Significance	N.S.	N.S.	N.S.	5%
Bosc				
Mist	5.1	5.0	13.8	40.6
Control	3.4	4.0	20.0	32.6
Significance	N.S.	N.S.	N.S.	N.S.
Interaction and significance				
Treatment x cultivar	1%		1%	

Mean separation in columns by Duncan's Multiple Range Test at the indicated level.

THE EFFECTS OF EVAPORATIVE COOLING FOR BLOOM DELAY ON 'BARTLETT' AND 'BOSC' PEAR MATURITY AND QUALITY[1]

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Abstract. Mature pear orchard misting and sprinkling and young pear hedgerow misting for bloom delay reduced fruit sizes of 'Bartlett' 6% and of 'Bosc' 12%. Harvest maturity, indicated by fruit pressure testing, was delayed 0 to 6 days for 'Bartlett' and 2 to 7 days for 'Bosc'. The effect of bloom delay on fruit size and maturity was greater on 'Bosc' than 'Bartlett'. Bloom delay had a greater effect on fruit sizing at harvest (3.5 days for every 6 days of bloom delay) than on harvest maturity (1 day for every 6 days delay). Soluble solids, not affected in pears from the mature plots, were slightly lower in the misted hedgerow. Titratable acids were not influenced by bloom delay.

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[1]Received for publication ________________. Portions from a thesis presented to the Graduate School of Oregon State University by the senior author, in partial fulfillment of the requirements for the MS degree.

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[4]Collins, M. D., P. B. Lombard, and J. W. Wolfe. 1977. Effects of evaporative cooling for bloom delay on 'Bartlett' and 'Bosc' Pear Tree Performance. Report to be submitted for publication Amer. Soc. Hort. Sci.

Evaporative cooling for bloom delay is a new approach to frost protection. Literature is scarce on the effects of bloom delay on parameters such as harvest maturity and fruit quality. Alfaro et al. (3) reported that sprinkling cherry and apple buds delayed bloom two weeks and harvest maturity one week for both species, but they observed no differences in fruit size or color. Bauer et al. (5) observed that bloom delay of 'Redhaven' peaches did not change sugar or protein levels of the fruit, but reduced yields. Our objectives were to evaluate bloom delay on 1) harvest maturity and 2) quality of 'Bartlett' and 'Bosc' pears.

Materials and Methods

Detailed descriptions of the test plots and evaporative cooling systems have been reported previously (6) (7). Fruit samples were taken when pressure tests indicated that control fruit were at an acceptable harvest maturity level. In 1975, each mature tree was divided into 8 sections--the 4 cardinal directions each in the upper and lower half of the tree where 20 fruit per section were randomly picked. All trees (6 'Bartlett' and 3 'Bosc') under the sprinklers and 15 (9 'Bartlett' and 6 'Bosc') in both the control and mist plots were sampled. In the hedgerow of young trees, 10 fruit samples were taken from each of 5 trees of Calleryana seedling (Call) and Old Home x Farmingdale (OH x F) rootstocks.

In 1976, the same trees were sampled in the mature orchard plots, but 25 fruit were picked at random from all parts of the trees since no statistical differences within the 8 sections were found in 1975. Sampling in the hedgerow was expanded to include 'Bosc' and sample size was increased to 25 fruit per tree. Trees on another P. communis rootstock (Naumes, Nau) were substituted for OH x F.

A measuring tray was used to determine fruit diameter and length for each sample. Fruit weight was recorded as kg per sample. Diameters, lengths, and weights were divided by total sample size to obtain size per fruit. Packing size classes (number of fruit per 43 lb. box), were measured by caliper and the weighted averages were used to represent the average size class. Firmness of flesh as a maturity indicator was measured by a Magness-Taylor pressure tester using a 5/16" diameter plunger. Three measurements were taken per fruit. A hand refractometer was used to determine soluble solids from juice extracted from quarter sections of each fruit. A 10 ml aliquot of juice was titrated to a pH 7.2 end-point on a pH meter using 0.1 N NaOH base. Titratable acid was determined in g of malic acid/100 ml of juice. Data were processed by analysis of variance and Duncan's Multiple Range Test.

Results and Discussion

Evaporative cooling of 'Bartlett' and 'Bosc' pear trees from January to April 1975 and 1976 delayed bloom 5 to 15 days[4] and also influenced harvest fruit sizes and maturity (Table 1). The bloom delay effected by cooling generally reduced fruit sizes of both cultivars. Mature orchard 'Bartlett' fruit weight was reduced 6% by misting in 1975. Using a 2.0% daily increase for 'Bartlett' fruit weight, based on the average rate of fruit growth in a 30 day period prior to harvest (2), this represents a harvest delay of 3 days. In 1976, mature orchard delayed 'Bartletts' were reduced 16%, a delay of 8 days. In the hedgerow, delayed 'Bartletts' were reduced 5% (2.5 day delay) in 1975 and 1976. This pattern was repeated in 'Bosc'. In 1975, using a 1.3% daily increase for 'Bosc' fruit weight, based on the average rate of fruit growth in a 30 day period prior to harvest (2), delayed bloom held back fruit sizes at harvest 12 days with a size reduction of 15% and, in 1976, 3.1 days with a 4% size reduction. There were no 'Bosc' in the hedgerow in 1975, but after cooling in 1976, fruit sizes were reduced 20%, or a delay of 15.4 days.

Three factor analyses of variance on the hedgerow fruit produced several significant interactions (Table 2). However, there was no significant treatment x cultivar interaction, indicating that, in this instance, bloom delay had the same effect on fruit size of early and later maturing pear cultivars, 'Bartlett' and 'Bosc'.

The treatment x rootstock interaction signifies a greater effect of bloom delay on Call rootstock as there was more reduction in fruit size of both cultivars by the mist on Call (22%) than on Nau (8%). There was also a cultivar x rootstock interaction which denotes larger fruit sizes with 'Bartlett'/Call than on Nau while 'Bosc' fruit were larger on Nau. A three-way interaction on fruit size, treatment x cultivar x rootstock, was also present indicating that the misted 'Bosc' on Call rootstock had the greatest effect in reducing fruit size (Table 2).

With one exception, the control treatments with earlier bloom had larger fruit than the bloom-delay treatments at harvest. The sprinkler treatment on 'Bartlett' in 1975 showed a 12% (6 day advance) larger fruit size. The low yield of 'Bartlett' in the sprinkler plots[4] could have influenced fruit sizes from increased leaf to fruit ratios (1). With this exception, bloom delay influenced harvest sizes not because of increased set, but because of the delayed development of fruit growth after bloom.[4] These fruit size reductions contrast with those in previous studies where no differences in apple size (3) (4) and increased peach size (5) on bloom-delayed trees were reported.

Harvest maturity, measured by pressure tests (kg), was delayed in 45% of the plots by the bloom delay. In 1975, bloom delay produced a 2 day delay in 'Bartlett' maturity (using a 0.14 kg daily pressure loss) in the mature orchard and a 6 day delay for hedgerow 'Bartlett' (Table 1). 'Bosc' pressures in 1975, which fell 0.06 kg/day, resulted in a 6.5 and 4.3 day delay for misted and sprinkled plots respectively (Table 2). However, in 1976 there was no significant delay in harvest maturity. In analyzing for interactions, only a cultivar to rootstock effect with pressure tests in the hedgerow was found, indicating both cultivars reached maturity sooner (lower pressures) on Nau rootstock (Table 2).

In other studies, peach maturity was not delayed (5), but apple maturity was postponed 1 week (3), on bloom-delayed trees. Generally, our data indicate that for a 6 day delay in bloom for 'Bartlett' and 'Bosc', fruit maturity was only delayed 1 day. However, the average fruit size reduction amounted to about 3.5 days for every 6 days bloom delay which makes it impossible for fruit to size during maturity as rapidly as pressures drop. The effect of bloom delay on fruit size and pressures at maturity was greater for 'Bosc' than 'Bartlett'. 'Bosc' normally matures about 25 days after 'Bartlett' so this delay in sizing and maturity could be critical for harvest conditions.

No consistent differences were evident in soluble solids of the mature orchard treatment for either year, but soluble solids of fruit in the hedgerow mist treatment were lowered (Table 1). Solids were significantly reduced in the misted hedgerow 'Bartlett', but not in the misted 'Bosc', which could be due to a greater crop density in the bloom-delayed hedgerow 'Bartlett' trees. The lowering of soluble solids in the bloom-delayed hedgerow pears could be attributed to 2 factors: a shorter growing season due to the delay, and an increased crop load.[4] The fruit of the older trees probably were less affected by the shorter growing season because of the greater photosynthetic reserves from a lighter crop load or a greater leaf to fruit ratio than on younger trees. Soluble solids is not a good maturity indicator for pears, although the reduced percent indicates a delay in accumulation of solids and conversion from starch in the pear at harvest. But there was a delay of only 4 to 6 days as calculated from periodic soluble solid measurements during harvest. Bauer et al. (5) found no reduction in fruit solids for peaches, but delaying apple bloom (3) reduced soluble solids and consequantly maturity by at least 7 days. Therefore, our study indicates a delay in soluble solids in bloom-delayed hedgerow 'Bartlett' and 'Bosc' pears comparable to that found for apples (3). Bloom delay had no measurable effect on titratable acids.

While avoiding frost conditions, bloom delay on 'Bartlett' and 'Bosc' pears generally resulted in a reduction of fruit size and a reduction of soluble solids of hedgerow trees at harvest. However, delaying pear harvest to comparable pressures would not result in comparable fruit sizes. The 'Bosc' cultivar had a greater size reduction at harvest and a greater delay of maturity than did 'Bartlett'.

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Table 1. Effects of bloom delay by evaporative cooling on fruit weight, flesh firmness, and soluble solids of 'Bartlett' and 'Bosc' pears in 1975 and 1976.

Cultivar and treatment	Fruit weight (g/fruit)		Flesh firmness (kg)		Soluble solids (%)	
	1975	1976	1975	1976	1975	1976
Mature orchard 'Bartlett'						
Mist	132c	150b	9.75a	8.30	12.9	12.5a
Sprinkler	161a	157ab	8.75b	8.39	12.5	11.9b
Control	141b	182a	9.12a	8.39	12.5	12.0b
Significance	1%	5%	5%	N.S.	N.S.	5%
Hedgerow 'Bartlett'						
Mist	130	137	8.44a	8.62	12.5	10.5b
Control	137	144	7.62b	8.85	13.0	11.8a
Significance	N.S.	N.S.	1%	N.S.	N.S.	5%
Mature orchard 'Bosc'						
Mist	139b	144	7.71a	7.67	14.8b	13.0
Sprinkler	134b	148	7.58ab	7.08	13.7a	13.1
Control	161a	152	7.30b	7.48	14.4b	12.4
Significance	1%	N.S.	5%	N.S.	1%	N.S.
Hedgerow 'Bosc'						
Mist	-	143b	-	8.30	-	12.0
Control	-	179a	-	8.16	-	12.4
Significance	-	5%	-	N.S.	-	N.S.

Mean separation in columns by Duncan's Multiple Range Test at the indicated level.

Table 2. Effects of bloom delay on size, flesh firmness, and soluble solid means and significant interactions in hedgerow 'Bartlett' and 'Bosc' pear trees in 1976.

	Fruit wt (g/frt.) Rootstock		Flesh Firmness (kg) Rootstock		Soluble solids (%) Rootstock	
Cultivar and treatment	Call	Nau	Call	Nau	Call	Nau
Bartlett						
Mist	137	122	8.71	8.53	10.9b	10.9b
Control	152	136	8.94	8.70	12.0a	11.6a
Significance	N.S.	N.S.	N.S.	N.S.	1%	1%
Bosc						
Mist	123b	163	8.80	7.76	11.9	12.1
Control	182a	175	8.57	7.76	12.6	12.2
Significance	1%	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction and Significance						
Treatment x rootstock	5%		--		--	
Cultivar x rootstock	1%		1%		--	
Treatment x cultivar	--		--		5%	
t x c x r	5%		--		--	

Comparable means in vertical columns with no letters in common are significant at the indicated level.

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APPENDIX

Table 1-A. Effects of evaporative cooling for bloom delay on length and diameter of 'Bartlett' and 'Bosc' pears in 1975 and 1976.

Cultivar and treatment	Fruit length/cm. 1975	Fruit length/cm. 1976	Fruit diameter/cm. 1975	Fruit diameter/cm. 1976
Mature orchard 'Bartlett'				
Mist	8.87	8.26	5.77c	6.24c
Sprinkler	8.35	8.29	6.14a	6.32b
Control	8.32	8.51	5.85b	6.61a
Significance	--	--	5%	5%
Hedgerow 'Bartlett'				
Mist	8.1	7.3b	6.4	6.0
Control	8.0	7.8a	6.1	6.1
Significance	--	5%	--	--
Mature orchard 'Bosc'				
Mist	9.54a	9.14ab	5.87b	6.06
Sprinkler	8.99b	8.49b	5.84b	6.27
Control	9.84	9.63a	6.07a	6.07
Significance	5%	5%	5%	--
Hedgerow 'Bosc'				
Mist	--	82b	--	5.8
Control	--	96a	--	6.7
Significance	--	5%	--	--

Data were processed by the analysis of variance and Duncan's Multiple Range Test. Comparable means in vertical columns with no letters in common are significant at the indicated level.

Table 2-A. Effects of bloom delay on average pack-out box count of 'Bartlett' and 'Bosc' pears in 1975 and 1976.

Cultivar and treatment	1975	1976
Mature orchard 'Bartlett'		
Mist	198	141
Sprinkler	178	142
Control	193	127
Mature orchard 'Bosc'		
Mist	195	150
Sprinkler	193	146
Control	185	149
Hedgerow 'Bartlett'		
Old Home x Farmingdale rootstock		
Mist	222	-
Control	208	-
Calleryana rootstock		
Mist	169	146
Control	176	141
Naumes rootstock		
Mist	-	158
Control	-	153
Hedgerow 'Bosc'		
Calleryana rootstock		
Mist	-	137
Control	-	127
Naumes rootstock		
Mist	-	132
Control	-	134

Table 3-A. Effects of bloom delay on titratable acid (g malic acid/100 ml) of 'Bartlett' and 'Bosc' pears for 1975 and 1976.

Cultivar and treatment	1975	1976
Mature orchard 'Bartlett'		
Mist	.22	.49
Sprinkler	.30	.43
Control	.32	.34
Significance	N.S.	N.S.
Mature orchard 'Bosc'		
Mist	.22	.24
Sprinkler	.21	.23
Control	.21	.19
Significance	N.S.	N.S.
Hedgerow 'Bartlett'		
Old Home x Farmingdale rootstock		
Mist	.29	-
Control	.28	-
Significance	N.S.	-
Naumes rootstock		
Mist	-	.35
Control	-	.37
Significance	N.S.	N.S.
Hedgerow 'Bosc'		
Calleryana rootstock		
Mist	-	.25
Control	-	.24
Significance		N.S.
Naumes rootstock		
Mist	-	.19
Control	-	.21
Significance		N.S.

Data were processed by the analysis of variance and Duncan's Multiple Range Test. Comparable means in vertical columns with no letters in common are significant at the indicated level.

Table 4-A. Effects of bloom delay on foliar content of mature orchard 'Bartlett' pear trees in 1975 and 1976.

	%						ppm				
Treatment	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
1975											
Mist	2.13b	.99	.17	1.56b	.35	11.66b	108.33	9.0	57.66a	23.50b	154.34
Sprinkler	2.14b	.99	.17	2.52a	.38	22.00a	93.33	7.84	38.50b	29.83a	151.67
Control	2.40a	.95	.18	1.74b	.38	23.16a	102.66	8.84	57.50a	28.33a	172.67
Significance	.05	NS	NS	.001	NS	.05	NS	NS	.001	.05	NS
1976											
Mist	2.01	1.12	.20	1.72	.44	23	67	7	46	94	205
Sprinkler	2.21	.91	.21	2.10	.41	29	92	8	44	103	264
Control	2.28	.98	.20	2.40	.45	30	85	8	43	99	237

Data in 1975 were processed by the analysis of variance and Duncan's Multiple Range Test. Comparable means for 1975 data in vertical columns with no letter in common are significant at the indicated level. Samples were composited in 1976 and therefore there is no statistical analysis.

Table 5-A. Effects of bloom delay on foliar content of mature orchard 'Bosc' pear trees in 1976.

Treatment	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
Mist	2.04	.67	.15	2.67	.38	25	63	6	31	108	227
Sprinkler	2.16	.69	.18	2.42	.38	52	77	7	35	108	350
Control	2.32	.65	.17	2.95	.39	26	79	7	35	94	316

Table 6-A. Effects of bloom delay on foliar content of hedgerow 'Bartlett' and 'Bosc' pear trees in 1976.

Cultivar, rootstock, and treatment	%						ppm				
	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
Bartlett/Naumes											
Mist	2.25	.94	.15	1.44	.47	31	79	6	47	78	208
Control	2.32	1.10	.18	1.51	.36	20	96	7	46	89	253
Bartlett/Calleryana											
Mist	2.14	.89	.15	1.74	.49	16	82	6	47	85	241
Control	2.32	.87	.18	2.68	.51	17	84	7	66	90	251
Bosc/Naumes											
Mist	2.45	.80	.15	1.40	.38	23	81	7	36	108	378
Control	2.52	.74	.16	1.76	.46	45	83	7	37	114	291
Bosc/Calleryana											
Mist	2.25	.98	.17	2.01	.39	18	79	7	47	114	305
Control	2.45	1.03	.15	2.20	.47	31	77	7	46	93	309