FINAL PROJECT REPORT **YEAR**: 1 of 1

Project Title: Improving fruit set, production efficiency, and profitability of pears

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[1]**Budget:** **Year 1:** $41,885
Other funding sources: None

Budget 1: Todd Einhorn
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Item	**2015**	**2016**	**2017**
Salaries[1]	10,997		
Benefits	7,368		
Wages[2]	18,200		
Benefits	1,820		
Equipment	0		
Supplies[3]	2,500		
Travel[4]	1,000		
Miscellaneous	0		
Total	41,885		

Footnotes: [1]Salaries are calculated as 3 months of Full Time Technician's salary and associated OPE using actual rates; duties include management of all experimental designs and field plots, operation of root pruner, PGR applications, plant measurements, and data management. [2]Wages are for 2 part-time employees to work a combined total of 1,400 hours ($13/hr) to aid in plot maintenance, plant measurements, and harvest; actual benefits rate is 10%. [3]Supplies intended to cover ethylene gas, carrier gases for GC, plant growth regulators, and electrical costs associated with operating growth chambers. [4]Travel is to cover weekly trips to the root pruning site in objective 2.

Objectives:

1. Develop ReTain, NAA and Ethephon protocols for increasing return bloom and fruit set in pear. Determine the effects of each of these on flowering, fruit set, and yield.

2. Complete a 3-year evaluation of root pruning in a high-density ‘d’Anjou’ planting. Characterize the effects of root pruning and potassium fertilizer on production and growth.

3. Evaluate the efficacy of metamitron as a thinner for ‘Bartlett’ pear.

Significant Findings

Objective 1:

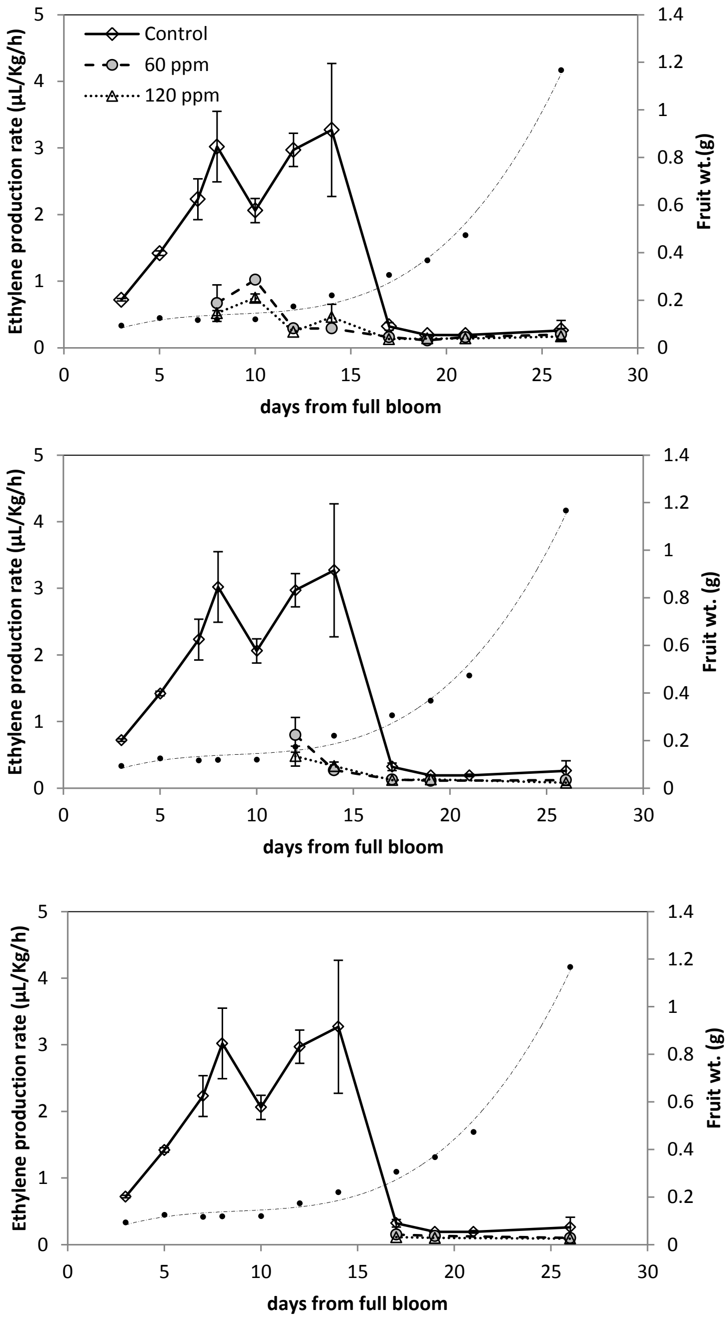
- ReTain applications improved fruit set and yield of mature Anjou trees by ~20% when applied just prior to, at, or after petal fall (i.e., 8, 12 or 16 days after full bloom).
- Application rates of ½ and 1 full pouch per acre were equally effective at increasing fruit set and yield.
- Natural ethylene production of untreated flowers and fruitlets increased ~4-fold from negligible production rates at bloom to maximum production rates ~ 14 days after full bloom, then declined sharply to values near 0 by 20 days after bloom.
- Applications of ReTain at 8, 12 or 16 days after full bloom markedly reduced ethylene production rates of flowers and fruitlets (i.e., ~30% of untreated levels).
- Ethephon 300 ppm applied 45 days after full bloom (performed in 2014) resulted in a 30% increase in return bloom and yield in 2015. Applications of 150 ppm did not result in a significant yield increase compared to untreated controls and 450 ppm had no benefits over the 300 ppm rate. These data support our earlier findings from 2013/2014.
- Ethephon 300 ppm applied 45 days after full bloom completely reversed the ~20% reduction of Anjou return bloom and yield from 2014 pro-hexadione calcium treatments (i.e., Apogee or Kudos).
- Four, weekly applications of NAA 5 ppm beginning 45 days after full bloom (performed in 2014) did not increase return bloom, fruit set or yield in 2015.

Objective 2:

- Root pruning both sides of 5th leaf Anjou tree-rows in 2014 at 1.5 ft. depth and distance from trees increased 2015 fruit set by 46% and resulted in a 40% increase in tree yield compared to controls. These data were similar to results reported in 2013/2014.
- Root pruning 4th leaf Anjou trees in a separate fertilizer trial in 2014 increased 2015 yield by ~35%. However, 2014 differential potassium applications were nullified by a grower decision to apply an aggressive fertilizer plan to the block in 2015.
- Fruit size of root pruned treatments was not significantly reduced in either experiment compared to controls as previously observed.

Objective 3:

- Metamitron effectively thinned Bartlett pears in a rate-dependent manner when applied at ~12 mm timing. The most efficacious rates required little to no follow-up hand-thinning. An earlier application (~6 mm) was not effective and did little to improve thinning when combined with the 12 mm timing.
- Metamitron reduced photosynthesis by 50% to 90% (relative to rate) for a two-week duration. This strong reduction of photosynthesis was associated with fruit abscission.
- The high levels of fruit drop from metamitron resulted in significantly larger fruit size compared to controls. Fruit quality at harvest and after storage was unaffected by metamitron.

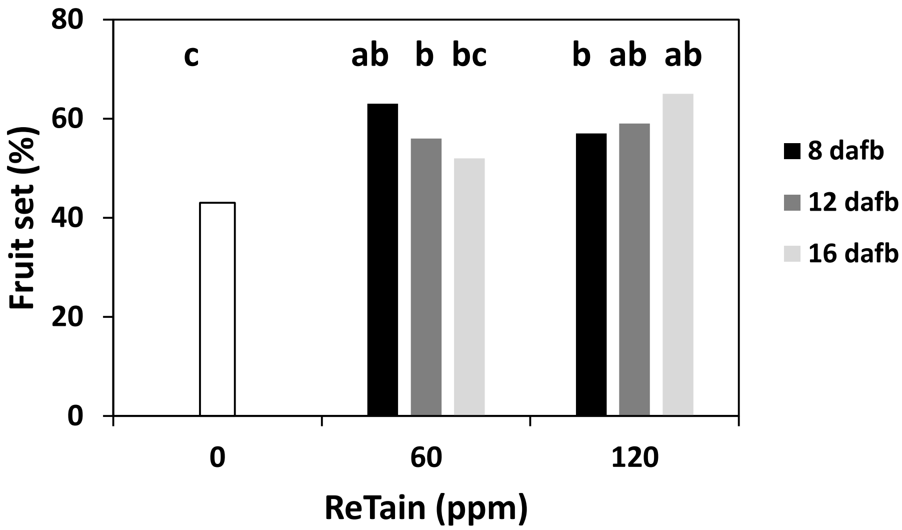


Results and Discussion

Objective 1 (PGRs):

ReTain: The active ingredient in ReTain (AVG) disrupts ethylene synthesis. Ethylene is a natural plant hormone that plays a strong role in senescence processes. The objective of using ReTain to improve fruit set is to reduce the production of ethylene in fruitlets that might otherwise induce abscission if left unchecked.

In past reports, we have documented a similar pattern of ethylene production from untreated pear flowers in different years (2013 and 2014) and of varying cultivars ('d'Anjou' and 'Comice') as steadily increasing from bloom to a maximum rate near 14 days after bloom, then rapidly declining to undetectable levels over the next few days. The application of ReTain significantly reduced ethylene production within 1 day in all cases; however, we observed a marked difference in the duration of the response induced by ReTain between years. In 2013 the response was strong and persisted for ~20 days, but in 2014, ethylene was only reduced for a few days after treatment. Despite the potential for long-lasting activity, we have never observed an increase in fruit set when ReTain was applied near full bloom. Collectively, these data informed us to target applications between petal fall and the peak of ethylene production (around 14 days after bloom). In 2015, we focused on a narrow range of timings using either ½ pouch (~60 ppm) or full-pouch (~120 ppm) rates per acre: 8 days after bloom; 12 days after bloom; and, 16 days after bloom. Whole trees were sprayed to runoff with a pressurized handgun. In all experiments a surfactant (Sylgard 309) was added to ReTain at 0.1% (v:v). ReTain markedly reduced, but did not completely inhibit, ethylene production of flowers and fruitlets at all timings (please see figure above). Consistent differences in the ethylene production rate were not observed for the half or full pouch ReTain rates; therefore, it appears that ½ pouch per acre saturates the response. The growth rate of untreated fruit is provided in all panels of the above figure for reference (dark circles with hashed line). ReTain did not reduce the growth rate of fruit (data not shown). Given the data, we would have expected no effect of ReTain on fruit set when applied at 16 days after bloom (lower panel) since ethylene production of untreated fruit was nearly undetectable at this time.



Fruit set was improved for all rates and timings of ReTain (see figure directly above). The full-pouch rate did not significantly increase the fruit set achieved with half rates at any timing. These data agree mostly with our previous findings, with the exception of a few trials where the full rate provided a slightly improved response than the half rate.

Treatment		Yield	Fruit wt.	Fruit firmness	Seeds
(timing)	(ppm ReTain)	(lbs/tree)	(g)	(lbs f)	(no./fruit)
Control	0	347 b	208.3 a	13.7	4.6
8 dafb	60	421 a	212.8 a	13.8	5
	120	399.3 ab	208.4 a	13.7	5
12 dafb	60	390 ab	205.9 a	14.1	4.6
	120	393.2 ab	196.5 ab	14	5.1
16 dafb	60	434 a	207.2 a	13.7	4.9
	120	420.3 a	187 b	13.6	5.3

Higher fruit set resulted in greater yields for most ReTain treatments relative to the untreated control (please refer to Table above). The fact that the 16 dafb application led to higher fruit set than controls is not clear. However, treatment timings were classified as days after full bloom and thus represent the average condition of the tree. While fairly uniform flower and fruitlet samples were collected for ethylene detection, the distribution of flower phenology would have comprised some portion of delayed blooms (bell-shaped curve), rendering that faction of flowers at the perfect stage for ReTain action resulting in greater set relative to the controls. Generally, ReTain increased fruit production by ~20%. Fruit weight, flesh firmness and seed count per fruit were largely unaffected by ReTain at harvest. The lack of difference in seed count among treatments indicates that ReTain did not set parthenocarpic (seedless) fruit, supporting our earlier observations.

Since beginning work with ReTain in 2012, we have documented an increase in fruit set and production in ~65% of trials.

In a separate series of experiments, we attempted to test the effect of temperature on AVG absorption and uptake using programmable temperature chambers. This work was designed to address the influence of application temperatures on the efficacy of ReTain. Shoots with sufficient flowers were sampled from the field and placed in test chambers held at either 35° F, 45° F, 55° F, 65° F, or 75° F then treated with ReTain. This approach was meant to mimic the range of temperatures likely when spray applications are made in the field, and to determine whether or not the temperature of plant tissue influences the uptake of ReTain. After drying, shoots were removed from chambers and flowers were weighed and placed in incubation tubes, sealed and held for 12 HRs at three temperatures designed to elicit a range of ethylene production rates (45° F, low ethylene rate; 65° F, moderate ethylene rate; 85° F, high ethylene rate). This portion of the experiment served to model post-application field conditions to describe their effect on uptake and activity of ReTain and characterize ethylene response to temperature. In all cases, treatments were compared to an untreated control (placed in separate chambers). Unfortunately, incubation temperatures (especially the two higher temps) led to increased humidity in the tubes which made detection on a gas chromatograph (GC) extraordinarily difficult. Because of the shift in retention time, the data were not reliable and are not reported. We are considering options to add a dehydration column upstream of the injection port so that we can attempt this work in 2016.

Ethephon and NAA: We have been evaluating ethephon for a few years to improve flower initiation and hence 'return' bloom the year subsequent to applications. For 'd'Anjou', flower initiation appears to occur around 50 dafb, hence our timing of 45 dafb. In 2012, 300 ppm ethephon applied at 50 dafb significantly increased 2013 yield by ~28%. The rate of 300 ppm was selected from reports using different cultivars and in different regions. Therefore, using a different set of trees in 2014, we repeated the experiment but tested several ethephon rates (150, 300 and 450 ppm). Return bloom, fruit set and return yield in 2015 were highest for 300 ppm ethephon (i.e., ~31% increase in production compared to controls; please refer to table below). Increasing the ethephon rate to 450 ppm did not improve the response. Conversely, the low rate of 150 ppm was not efficacious; hence, 300 ppm ethephon is the appropriate rate to increase return bloom of Anjou in the mid-Columbia region. Further, we applied ethephon to trees treated with two applications of prohexadione-calcium (active ingredient in Apogee and Kudos) to reduce vigor. In the past, we have documented reduced return bloom associated with prohexadione-calcium. Ethephon completely reversed the adverse effect of Kudos on return bloom (see table below) resulting in strong vigor control without sacrificing return bloom.

	Return bloom		Return yield and fruit wt.		
Treatments	Spurs	1-yr shoots	Yield per tree	Fruit per tree	Avg fruit wt
	%	%	lbs	no.	g
Control	43 b	42 b	251 b	534 b	212
Kudos 250 ppm	**17 c**	**13 c**	**184 c**	**365 c**	227
Kudos + 450 Eth	43 b	34 b	246 b	504 b	220
Kudos + 300 Eth	**57 ab**	**28 bc**	**274 ab**	**610 a**	203
Ethephon 150 ppm	49 b	50 ab	262 b	546 b	217
Ethephon 450 ppm	**48 b**	**49 b**	**305 a**	**659 a**	209
Ethephon 300 ppm	**64 a**	**60 a**	**330 a**	**634 a**	235

The use of NAA, applied weekly at low concentrations (5 ppm) beginning 45 dafb did not improve return bloom or yield of 'd'Anjou' trees (data not shown). This protocol has been successfully applied to apple

Objective 2 (Root Pruning):

Root pruning was performed in commercial orchards prior to bloom when ~10% of the flowers were open. The implement (fabricated by Mr. Herbie Annala, Hood River producer) was tractor mounted and pulled in low gear ~1.5 ft. from tree trunks down either one or two sides of the tree row. Root pruning treatments were compared to untreated control trees in randomized complete block designs, replicated four times throughout the orchard. Whole rows were treated in experiment 1; in experiment 2, replicates comprised 8 contiguous trees. The depth of the steel shank was 1.5 ft. and the angle was 5 degrees off from the vertical (angle facing into the tree row). All other cultural practices were performed according to commercial standards.

Experiment 1: 2014/2015 5th and 6th leaf 'd'Anjou'/OHxF 87 (4 ft. x 12 ft.) Trial- In 2014, we documented a two-fold increase in the return yield of root pruned 'd'Anjou' pear trees (root pruned in 2013 [4th leaf]) - this represented a per acre improvement of ~ 20 bins. Root pruning reduced shoot length by ~ 20% the year of application, and trunks were 30% smaller after the second year. Hence, the yield efficiency of root pruned trees in 2014 was markedly higher than untreated trees, fulfilling the primary objective of root pruning. These results were in contrast to an earlier experiment whereby root pruning negatively affected fruit set, yield, and fruit size of 6th leaf 'd'Anjou' trees in the year of application. In that trial, root pruned trees had higher return bloom, fruit set and yield in the subsequent year but not enough to compensate for the yield reductions of year 1. We surmised that root pruning was too severe for the age of the trees and, ideally, should be performed earlier in the life of the orchard.

In 2015, we either root pruned trees in consecutive years (i.e., 2014 and 2015) or applied root pruning to previously untreated, 6th leaf trees. In all cases root pruning was performed to both sides [i.e., 2xRP] of the tree row at a depth and distance from trees of 1.5 ft. In contrast to previous experiments, we observed a ~20% increase in yield the year of application of root pruning when trees had not received previous root pruning treatment (see table below). The effect of consecutive years of root pruning resulted in a 40% yield improvement relative to control trees. While a slight reduction in fruit weight was observed for trees receiving root pruning for the first time in 2015 (as previously shown) the reduction was not significant.

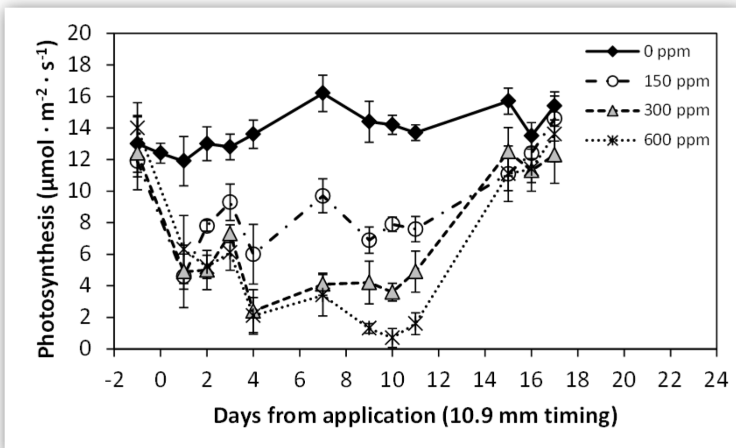
Treatment 2014/2015	Tree yield (lbs/tree)	Fruit per tree (no.)	Avg. fruit wt. (g)
Control/Control	49.1 b	98.2 b	223.9
Control/2x RP	59.4 ab	137.4 a	199.3
2x RP/2x RP	68.8 a	143.6 a	216.2

We did not quantify the response on shoot growth or vigor, since we have thoroughly documented these responses in previous reports, though shoots were visibly shorter in trees root pruned for the first time in 2015 (i.e., estimated to be ~1/4 to 1/3rd reduced).

Experiment 2: 2015 5th leaf 'd'Anjou'/OHxF 87 (4 ft. x 12 ft.) Potassium Trial- We have also been evaluating the effects of potassium fertilizer in combination with root pruning. Potassium is mobile in soils but could potentially become limiting when severely reducing the rhizosphere (i.e., root pruning). Moreover, potassium has been positively associated with fruit size and fruit size is often compromised by root pruning. In 2014, three levels of potassium (low, moderate and high) were applied with and without root pruning. Root pruning was applied as described above in Experiment 1. In 2015, we compared trees that were root pruned in 2014 but not root pruned in 2015 and trees that were root pruned consecutively (i.e., 2014 and 2015 2x RP) to untreated controls. We intended to continue disparate potassium fertilizer treatments but, unfortunately, the grower entered a contract with a fertilizer company to treat the block uniformly using a different approach. Consequently, we were not able to evaluate the effects of potassium and its interaction with root pruning on yield and fruit relations. We did, however, harvest the block and compare the production of control trees to those root pruned. Root pruning resulted in a 35% increase in yield relative to untreated controls, irrespective of whether root pruning was re-applied in 2015 or not (see table below).

Treatment 2014/2015	Yield (lbs/tree)	Fruit no. (fruit/tree)	Fruit wt. (g)	Fruit firmness (lbf)
Control/Control	33.9 b	69.7 b	220.6	12.4
2x RP/Control	47.2 a	89.2 a	239.3	12.8
2x RP/2x RP	45.5 a	85.2 a	241.8	12.4

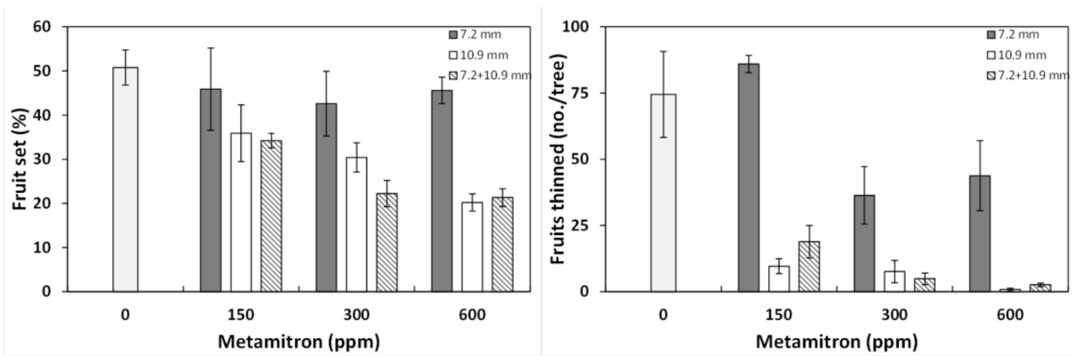
With the exception of one trial, root pruning has consistently led to greater 'd'Anjou' yields when applied to 4th, 5th and 6th leaf trees. Our previous experiments indicated that root pruning one side only was largely ineffective. Fruit size has typically been reduced the year of application, though we did not observe this in 2015.



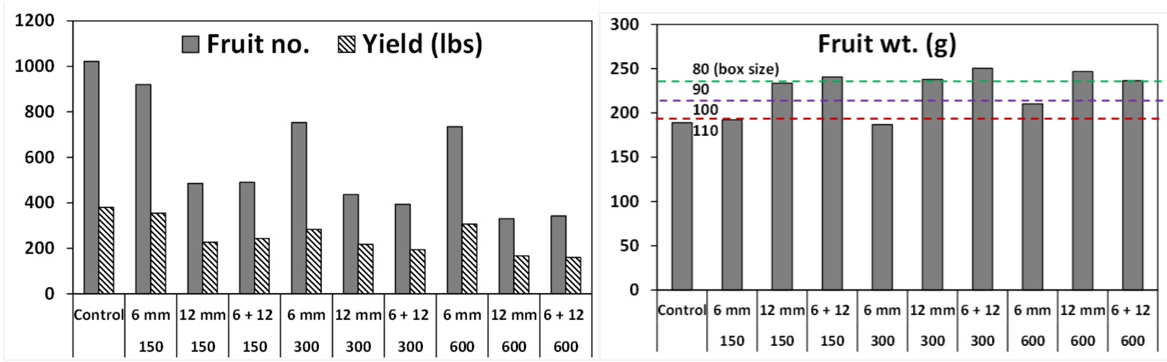
Objective 3 (Thinning):

Rates of metamitron (150, 300, 600 ppm) were chosen based on a previously published trial using 'Conference' pear in The Netherlands that produced a range of fruitlet abscission from relatively little to excessive. For each of the three rates evaluated, we tested two application timings (6 mm and 12 mm), alone and combined. Our selection of a mature block of Bartlett trees (i.e., ~40-year-old trees) was predicated on our previous thinning work whereby older trees with presumably high reserve carbohydrates were able to withstand short periods of reduced photosynthesis (induced by alternative thinning compounds) without a concurrent increase in fruitlet thinning, compared to younger trees. From this work we hypothesized that a potentially large reserve carbohydrate pool might supply sufficient carbon to meet fruit growth demands despite a reduction in incoming carbon from photosynthesis. Metamitron reduced photosynthesis by ~50% to 90% depending on rate (please refer to figure at left). Interestingly, all rates reduced photosynthesis for approximately two weeks. The lack of measurements between 11 and 15 days from application, however, may have obscured actual differences among rates in the duration of the effect.

Fruit abscission was strongly associated with metatmitron rate (see upper figure on next page). Rates of 150 and 300 ppm reduced the crop load of untreated control trees by ~25% to 40%. The 6 mm timing (actually 7.2 mm) had relatively no thinning efficacy; therefore, the combination of early and late timings differed little from the 12 mm timing (actually 11.2 mm), which thinned exceptionally well. After evaluating fruit set and thinning efficacy, we lightly hand-thinned all trees to reduce clusters of 4 or more fruit. The level of hand thinning required was proportional to the thinning efficacy of the different rates and timings (see upper figure on next page). Treatment yields reflected the relative number of fruits removed by chemical and hand thinning (see lower figure next page). Fruit size was improved for all 12 mm application rates and was clearly a function of crop load (see lower figure next page). We note, however, that a commercial level of hand thinning was not applied to untreated control trees. Therefore, a crop level between the control and 150 ppm (11.2 mm timing) may have been optimal to achieve good balance between fruit size and yield. Future work is proposed to refine application rates. No adverse effects were observed for any fruit quality attributes (fruit firmness, soluble solids, titratable acidity, and fruit finish (i.e., russet) evaluated at harvest and after 3 months of cold storage (data not shown).



Caption to above figure. The effect of metamitron rate (0, 150, 300 and 600 ppm) and timing (7.2 mm, 10.9 mm and 7.2 mm + 10.9 mm) on fruit set of ‘Bartlett’ pear flowers (expressed as % fruits per 500 clusters) left, and fruits removed by a light, follow-up hand thinning ~40 days after full bloom (right). Bars are the mean of 5 single-tree replicates +/- standard error.



Caption to above figure. The effect of metamitron timing (upper x-axis; 7.2 mm, 10.9 mm and 7.2 mm + 10.9 mm) and rate (lower x-axis; 150, 300 and 600 ppm) on the total number of fruits and yield per tree (left), and fruit size at harvest (right), compared to a control. Box sizes (no. of fruit per 44 lb box) are provided for comparison using hashed horizontal lines in right panel. Bars are the mean of 5 single-tree replicates (n= 100 [individually weighed fruit per tree]). Harvest began when flesh pressures reached 18 lbf.

Executive Summary:

PGRs

•ReTain applications improved fruit set and yield of mature 'd'Anjou' trees by ~20% when applied just prior to, at, or after petal fall (i.e., 8, 12 or 16 days after full bloom).

•Application rates of a half pouch per acre were sufficient to optimize the effect on fruit set and yield.

•Natural ethylene production of untreated flowers and fruitlets increased ~4-fold from negligible production rates at bloom to maximum levels ~ 14 days after full bloom, then declined sharply to values near 0 by 20 days after bloom.

•Applications of ReTain at 8, 12 or 16 days after full bloom markedly reduced ethylene production rates of flowers and fruitlets (i.e., ~30% of untreated levels).

•Ethephon at a rate of 300 ppm applied 45 days after full bloom (performed in 2014) increased 2015 return bloom and yield by ~30% compared to untreated controls. 150 ppm ethephon did not affect flowering or production in 2015 and 450 ppm ethephon had no appreciable benefits compared to the 300 ppm rate.

•Ethephon at a rate of 300 ppm applied 45 days after full bloom in 2014 completely reversed the ~20% reduction in return bloom and yield caused by 2014 pro-hexadione calcium treatments (i.e., Apogee or Kudos).

•Four, weekly applications of NAA (5 ppm) beginning 45 days after full bloom (performed in 2014) did not increase return bloom, fruit set or yield of 'd'Anjou' in 2015.

Root Pruning

•Root pruning both sides of 5^{th} leaf Anjou tree-rows in 2014 at 1.5 ft. depth and distance from trees increased 2015 fruit set by 46% and resulted in a 40% increase in tree yield compared to controls. These data were similar to results reported in 2013/2014.

•Root pruning 4th leaf Anjou trees in a separate fertilizer trial in 2014 increased 2015 yield by ~35%. However, 2014 differential potassium applications were nullified by a grower decision to apply an aggressive fertilizer plan to the block in 2015.

•Fruit size of root pruned treatments was not significantly reduced in either experiment compared to controls as previously observed.

Thinning

•Metamitron effectively thinned Bartlett pears in a rate-dependent manner when applied at ~12 mm timing. The most efficacious rates required little to no follow-up hand-thinning. An earlier application (~6 mm) was not effective and did little to improve thinning when combined with the 12 mm timing.

•Metamitron reduced photosynthesis by 50% to 90% (relative to rate) for a two-week duration. This strong reduction of photosynthesis was associated with fruit abscission.

•The high levels of fruit drop from metamitron resulted in significantly larger fruit size compared to controls. Fruit quality at harvest and after storage was unaffected by metamitron.