

resistance is that experienced with 'Magness'. Even though this cultivar is highly resistant to twig blight, susceptibility of the trunk has been demonstrated experimentally and infection was induced both by natural and artificial inoculation, causing death of many trees from girdling (6). However, this type of blight has been observed only under severe blight conditions at Beltsville and is expressed rarely in commercial 'Magness' orchards. Another example is in the cultivar 'Dawn'. Based on twig inoculation tests, Thompson et al. (5) reported the reaction of this cultivar to be between 'Kieffer' and 'Bartlett'. On the basis of our observations on a large number of older trees, however, 'Dawn' has shown a remarkable degree of resistance, even under severe blight conditions. An interesting observation was made on 'Mac'. By 1972, 5 of the 6 trees were about 20% blighted down the central leader. Since then, blight has not progressed any farther and today all trees appear to have completely recovered.

Finally, it is of interest to compare natural blight damage in mature pear

trees with damage in younger trees due to artificial inoculation in succulent shoots. Our findings agree with previous studies by Lamb (2) and Thompson et al. (5) based on artificial inoculation. In these reports, cultivars such as 'Maxine' and 'Kieffer' are listed as resistant, whereas 'Bartlett', 'Beierschmitt', and 'Clapp Favorite' are listed as susceptible. The 4 resistance classes used by Thompson et al. (5), based on average length of blighted tissue per tree, are basically similar to our 4 resistance classes used in Table 1.

This 6-year study of natural blight incidence in the collection of major pear cultivars at Beltsville has shown that the use of lowest blight scores as a measure of resistance for susceptible cultivars to be fairly reliable but somewhat misleading for resistant cultivars. Ratings for resistant cultivars should therefore be based on a large number of trees. In small tests, where only 2 trees are planted, the use of the lowest score is valid only in cases where this score was obtained quickly within a few years, indicating that blight progressed rapidly and the cultivar was thus truly susceptible. Generally, fire blight

progresses slowly in trees of resistant cultivars.

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## Fruit Set as Related to Girdling, Early Cluster Thinning and Pruning of 'Anjou' and 'Comice' Pear<sup>1</sup>

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**Abstract.** Tests with pear on *P. communis* L. and 'E. M. Quince C' (*Cydonia oblonga* Mill.) rootstocks showed that early fruit thinning to 1 fruit per cluster increased ultimate % fruit set of 'Comice'; thinning to 2 fruits per cluster did not increase ultimate set. Limb girdling 3 weeks after bloom did not effectively increase set, but when used in combination with cluster thinning, increased 'Anjou' set beyond either treatment alone. Heading-back pruning of 'Comice' on 'Quince C' in a high density plot increased both fruit set and ultimate yield relative to thinning-out pruning.

The general concept of fruit set is that gibberellin (GA) is produced by immature seeds following pollination and fertilization, and that GA, if applied to unfertilized flowers of the same species induces set (2). Also it was found that soon after GA synthesis or application, auxin levels in the fruit rise (7). Application of either GA or synthetic auxins are widely known to

increase fruit set in many species. In addition to GA and auxin, cytokinins appear to influence fruit set in the apple. Williams (12) showed that nitrogenous factors from the roots, as a result of late summer nitrogen applications, resulted in greater embryo sac longevity, more cell divisions and better fruit set the following spring. The later work of Luckwill and Whyte (5) indicated that cytokinins and an auxin-like hormone move up from the roots in xylar sap in early spring, reaching a peak at full bloom, diminishing to very low levels by mid-summer. Thus any treatment or condition which would alter the levels of GA, auxin, or cytokinins at critical times could alter set.

Considerable work has been done to show the effect of cross pollination on set of pear, most cultivars of which are self sterile (4, 8). Low ultimate set of 'Anjou' and 'Comice', however, from year to year cannot always be related to poor pollination or even to low temperature and poor subsequent pollen tube growth.

Chemicals such as dormant oil have

increased set (4), while late sprays of lime-sulfur and oil have decreased set (3). Fall sprays of 2,4,5-trichlorophenoxypropionic acid often increase set (10), as do spring or fall sprays of boron in some cases (1).

Other factors such as nitrogen fertilizer, pruning, and rootstocks also affect set (4, 6, 9, 11). While Preston (6) reported better cropping with non-pruned 'Comice' on quince, Lombard et al. (4) and Westwood et al. (9) reported greater set and yield of 'Anjou' which were pruned. In another study (E. S. Degman, personal communication) limb girdling of mature 'Anjou' trees at full bloom resulted in a 40% reduction of set above the girdle but a 35% increase in set below the girdle. But if girdling was done 7 weeks after bloom, then the effect on set was reversed.

Carryover effects from one year to the next also are known. Poor mite control in one year has reduced set of 'Anjou' the next year (4). Previous years' seeded crops induced seedless set of 'Anjou' without cross pollination for at least 3 years after the last seeded crop (10).

The present study was done to learn the single and interactive effects of early fruit thinning and girdling on set of 'Anjou' and 'Comice' and to further study the effect of pruning on set of 'Comice' since the literature on this point is contradictory.

In the first test, mature 15-year-old 'Anjou' and 'Comice' trees on 'E. M.

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Quince C' and on *P. communis* roots were used. Six heavily flowering branch units per treatment were used on each cultivar and rootstock, and treatments and replicates were assigned at random. Girdling and thinning were done 3 weeks after full bloom, at which time initial fruit set was apparent. Clusters were either thinned to a single fruit per cluster (singles) or alternate clusters were left with 2 fruits (doubles). In each case, the same number of fruit was left on the limbs.

The second test was done in an 8-year-old block of 'Comice' on 'E. M. Quince C' planted 4.6 x 1.2 m (726 trees/acre). The 2 pruning methods were "thinning-out" only and "heading-back" only. Thinning-out cuts were those where the entire limb was removed back to its point of origin, with heading-back, branches were cut back to about half their length. Approximately the same amount of wood was removed in each case. Four replicates of 5 trees each were used for each treatment. In both tests, the randomized block design was used, and statistical evaluation was by analysis of variance.

Girdling alone 3 weeks after bloom appeared not to increase fruit set, while thinning to a single fruit per cluster with 'Comice' increased ultimate set over controls (Table 1). This is probably also true for 'Anjou'. The combination of girdling plus thinning to singles, increased set in every test in which the treatment occurred. Where thinning to 2 'Anjou' fruits per alternate cluster was done, set was similar to the controls. This suggests that some local competitive factor or set inhibitor exists which preferentially induces heavier natural drop on spurs possessing 2 or more fruit during the period of final fruit set. Both 'Comice' and 'Anjou' often have heavy initial set, only to lose most of their fruit in this second drop. Our data suggest that this drop would not be as heavy if the initial set was predominantly a single fruit per cluster.

We do not understand why girdling is strikingly more effective when used in combination with thinning to singles (Table 1). This may be due to a shift in competitive sinks or to a change in the complex hormonal balance. In either case, it involves the phloem transport system. Degman's data showing an increase in set below an early girdle and a decrease in set above it indicate that possibly an abscission factor is moving downward, but most likely a setting factor is translocated upward in the phloem in early spring. The girdle would trap such a substance below the girdle and thus diminish it above the girdle. The reversal of this effect if girdled at 7 weeks past bloom might occur if the setting factor were later produced by the developing leaves, shoots or

Table 1. Effects of limb girdling and fruit thinning 3 weeks after full bloom on ultimate set of 'Anjou' and 'Comice' pears grown on 2 different rootstocks.

Treatment	% Set <sup>2</sup>			
	Anjou		Comice	
	Rootstock <i>P. communis</i>	Quince C	Rootstock <i>P. communis</i>	Quince C
Girdled	28	22	—	17
Thinned to singles	30	33	66	65
Thinned + girdled	46	55	—	60
Thinned to doubles	15	—	—	—
Control	16	23	24	15
LSD 5%	15	11	20	17

<sup>2</sup>Set as % of the no. fruits remaining immediately after thinning.

embryos and was translocated downward in the phloem. Our girdling in the present tests may have been too early for maximum effect on set above the girdle. In fact, it appears that nearly all of the work done on girdling of pear to increase set has been done too early. This contrasts with apple in which girdling is most effective for set if done between full bloom and 2 weeks past bloom.

In test 2, the data show a striking fruit set response to heading-back pruning compared to thinning-out (Table 2). This is somewhat similar to earlier tests with 'Anjou' in which heavier pruning increased both set and yield, particularly if the trees were in a state of low vigor (9). The somewhat crowded tree-wall system and the dwarfing quince rootstock resulted in low vigor in the present test. But 'Bartlett' and 'Bosc' on *P. communis* root in earlier studies (9) showed an opposite effect, i.e. yield was greatest with no pruning. Preston (6) also reported that 'Comice' on 'Quince A' yielded more fruit during the first 7 years on unpruned rather than pruned trees. However, he reported that % fruit set was greater when trees were pruned. Clearly, the reduction in yield from pruning was because pruned trees were smaller than unpruned ones. In Preston's test, trees were spaced 4.6 x 3.7 m (240 trees/acre), compared to ours of 4.6 x 1.2 m (726 trees/acre). Thus his limiting factor was bearing surface while we had adequate bearing surface even with moderate pruning.

Several possible explanations can be made for the pruning data. Pruning results in greater vigor of remaining branches which might result in higher levels of a fruit setting factor such as auxin. Heading-back pruning tends to

increase the vigor of terminal shoots, compared to thinning-out pruning. On the other hand, if a setting factor (possibly auxin) resides in the roots and moves upward in the spring as previously suggested (7), then heading-back pruning would concentrate it in fewer growing points in close proximity to the flower cluster than would long-pruned or unpruned trees. We noted that in most cases, regardless of pruning system, the heaviest fruit set occurred near the ends of branches, a further indication that either a systematic setting factor moves up and concentrates at the ends of branches or else the vigorous shoots produce a set factor. The girdling effect indicates that phloem transport is important, yet a previous study (10) suggested that a setting factor was transported in the xylem. The greater fruit drop resulting from thinning to doubles rather than single fruits indicate that a very localized abscission factor, possibly ethylene, is being produced by the fruits themselves. If the abscission factor were being produced elsewhere and transported to the clusters then singles should set no better than doubles. The explanation that doubles are subjected to stronger competition for carbohydrates and other nutrients does not seem appropriate to our data, since the same number of fruits existed in both cases, and carbohydrates are readily translocated from nearby leaves.

The problem of optimizing pear fruit set in order to obtain target yields of 67.2 metric tons/ha (30 tons/acre), which have been achieved during some years is a complex one. From the literature cited and the data presented here, ultimate set of pome fruits is affected by the obvious factors of pollination and fertilization (2, 4, 8)

Table 2. Effect of pruning method on set and yield of 'Comice' pear on 'E.M. Quince C' grown in a dense hedgerow spaced 4.6 x 1.2 m (726 trees/acre).

Pruning treatment	Fruit set (no./100 clusters)	Yield		
		(kg/tree)	MT/ha	T/acre
Thinning-out only	14	8.2	14.6	6.5
Head-back only	31	15.4	27.6	12.3
LSD 5%	6	6.8	—	—

and also by nutrition (1, 9, 12), rootstock (5, 11), auxin balance (7, 10), previous pest control (4), chemical sprays (3, 4, 10), girdling, thinning, and pruning. The primary effect of all these factors probably is to alter the hormonal balance in the fruit and nearby twigs. Much work remains to be done to evaluate these factors and to determine their critical interactions.

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## Cold Storage and Handling of Red Raspberry Planting Stock<sup>1</sup>

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**Abstract.** Plant mortality from early April or later plantings of dormant 'Willamette' red raspberry (*Rubus idaeus* L.) stock dug from propagation field in February and placed in cold storage (-1.1° and 1.7°C) was never higher than 3.1% as compared to as high as 24% from heeled in and freshly dug plants. Cold-stored plants produced comparable growth to heeled in and freshly dug plants. Pre- and postharvest dips with N-[(trichloromethyl)thio]-4-cyclohexene-1,2-dicarboximide (captan) and methyl 1-(butyl carbamoyl) 2-benzimidazolecarbamate (benomyl) did not influence mortality or plant growth, nor did the addition of sawdust, peat moss or vermiculite as moist packing materials in cold storage. Planting stock with cane diameters greater than 6.4 mm had lower mortality and produced more growth than stock with canes less than 6.4 mm in diameter. Plant growth from propagation stocks was negatively correlated with planting date.

Dormant red raspberry plants from propagation fields in the Pacific Northwest are normally dug in Jan. and Feb. but sometimes delayed until April. This planting stock may be planted immediately or may be temporarily heeled in outdoors until conditions are suitable to establish a new field. Frequently new fields are not planted until April, or even May. These procedures are not satisfactory as plant mortality is often high and first year growth poor. This study was undertaken to determine if good plant survival and growth could be obtained from dormant red raspberry plants held in cold storage similar to storage conditions used for dormant strawberry plants (1).

Dormant 'Willamette' red raspberry plants for a series of experiments were dug from a certified propagation field on Feb. 22, 1972 and Feb. 5, 1973 and prepared for cold storage by trimming the canes to approx 15 cm, tying in bundles and placing in perforated 1.25-mil polyethylene bags in cardboard boxes. Plants for heeling in were also trimmed to 15 cm, tied in bundles and were heeled in outdoors in fumigated sandy loam soil. After cold storage or heeling in, plants were planted in the field in a randomized complete block with 12 replications of 6 plant plots in 1972 and 10 replications of 8 plant plots in 1973.

For each experiment observations of plant mortality, no. of canes over 0.9 m (36 inches), no. of canes over 1.2 m (48 inches), and fresh wt of top growth per plot were made in Sept. of each year. Observations were adjusted upwards for plots with missing plants due to mortality by multiplying by the no. of plants set divided by the no. of surviving plants to permit the separation of mortality and growth responses.

*Cold storage vs. heeling in.* Plants were subjected to the following treatments in both years: a) cold storage in walk-in units at -1.1° ± 1.0°C, b) cold storage at 1.7° ± 1.0°C, c) heeling in outdoors, and d) digging from the propagation field and planting in the new field on the same day (dig and plant treatment). Moist sawdust was used as a packing material to maintain moisture within the polyethylene bags in the 1972 trial only. Plants were heeled in or held in cold storage until March 29, April 12, April 26 and May 10 in 1972 and until Feb. 26, March 19, April 9, April 30 and May 21 in the

1973 trials and then planted in the field. At each date plants were dug from the propagation field for the dig and plant treatment.

There was considerable variation in the extent of bud break and lateral growth from the dormant plants while in cold storage and while heeled in. In -1.1°C cold storage no growth occurred during the 15 week period. In 1.7°C cold storage no growth occurred for 6 weeks but by 12 weeks 2.5 cm and by 15 weeks 3.8 cm of etiolated lateral growth had occurred. Heeled in plants had up to 7.6 cm of new growth by March 20, 15.2 cm by April 10, and 40.6 cm by May 22. Plants of the dig and plant treatment had approx the same growth as the heeled in plants.

Plant mortalities for the heeled in and for the dip and plant treatments were not significantly different from each other at each planting date in both years. Plants stored at -1.1°C and at 1.7°C were also not significantly different from each other in mortality at each planting date. Therefore, mortality data (Fig. 1) are presented as means of the heeled in and dig and plant treatments and means of the 2 storage treatments. After the March 29 planting date mortality of the dig and plant and heeled in plants increased dramatically to 24% on May 21, while that of cold stored plants increased slightly to 3.1%. Plants in cold storage for as long as 11, 12 and 15 weeks had very low mortality, 2.1, 3.1 and 3.1%, respectively. The high mortality of heeled in and dig and plant treatments in April and May in comparison with the cold stored plants may be related to broken dormancy.

Number of canes and weight of top growth for the dig and plant, heeled in and cold storage treatments showed considerable year to year variation indicating no clear cut differences due to treatments (Table 1).

Low mortality and good plant growth was achieved by planting dormant plants that had been in -1.1°C

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