Spur Extinction
– a natural process leading to a new crop management technology

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In the May edition of AFG, the PIPS Tree Structure team detailed the importance of tree structure in optimising productivity of Australian apple orchards. In this article, they introduce the new crop management tool 'Artificial Spur Extinction'.

Spur extinction – the natural process

Flowering and fruiting in apple trees are affected by environmental, developmental and genetic (cultivar) factors. The two factors that determine year-to-year differences in vegetative growth and fruiting are (Lauri *et al.*, 1995; Lauri *et al.*, 1997):

1. **Bud abortion rate:** The proportion of growing points (buds) that abort in the canopy every year. Bud abortion typically occurs on floral buds that fail to set fruit and is called 'spur extinction' *(Figure 1A)*.
2. **Quantity of independent growing points:** Independent growing points that remain after bud abortion can switch from vegetative to floral and/or remain floral and lower biennial bearing.

Apple cultivars that express both tendencies have a natural mechanism that balances reproductive and vegetative growth. This enables floral buds that bear fruit to produce strong spurs/bourse shoots *(Figure 1A)* capable of flowering the following spring. This process is known as the 'bourse-over-bourse' potential and is the developmental origin of cultivars with regular cropping characteristics.

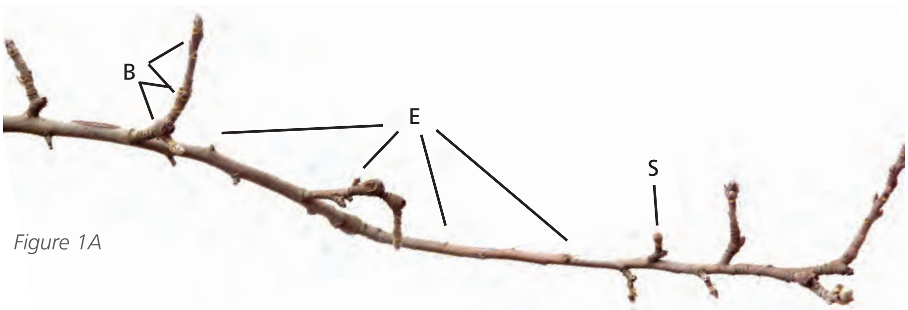

Figure 1A


Figure 1B

Figure 1A: *Fruiting branch of a 'regular bearing' apple ('Granny Smith') showing a low spur (S) density with numerous 'extinct spurs' (ES) and a high frequency of bourse shoots (BS) on bourses (B).*

Figure 1B: *Fruiting branch of a 'biennial bearing' apple ('Red Chief Delicious') showing a high spur density with few 'extinct' spurs and no bourse shoots.*

Bearing types

As a generalisation, apple cultivars tend to fit into two groups:

1. **Regular bearers:** These cultivars have a high natural spur extinction. Also many of their newly formed spurs and bourse shoot terminal buds of fruit-bearing sites return to flower the next spring e.g. 'Granny Smith', 'Cripps Pink' and 'Royal Gala' *(Figure 1A)*.
2. **Biennial bearers:** These cultivars have a low rate of natural spur extinction and a very low ability for newly-produced spurs on fruit-bearing sites to flower the next spring e.g. spur-type 'Red Delicious', 'Braeburn', 'Fuji' and 'Golden Delicious' *(Figure 1B)*.

Differences in floral spur longevity of these two fruiting types leads to distinctive and different fruiting branch structures. Regular bearers retain a low density of active spurs interspersed with numerous extinct spurs. The structure of active spurs often includes an extended short bourse shoot with a terminal fruit bud *(Figure 1A)*. Whereas biennial bearers have a high density of active spurs, very few bourse shoots and few extinct spurs *(Figure 1B)*.

Artificial Spur Extinction – a new crop management technique

Artificial Spur Extinction (ASE) is a new crop management technique that reduces floral bud density of the tree canopy. This helps the tree to flower each year to support regular bearing and to continue to produce strong fruit buds. This process mimics the natural bud abortion that occurs with regular bearing apple cultivars.

The term 'artificial' refers to manually removing floral spurs to systematically reduce the total number of floral buds of fruiting branches. Artificial Spur Extinction is implemented as an **additional tree management procedure** following winter pruning, as the first major step in crop load management. Typical tree pruning and training requirements are not replaced by ASE.

Limitations of present orchard production technologies to control crop load

Setting crop load is the crucial aspect of orchard management because it controls orchard yield potential, fruit size distribution and fruit quality (so determines the crop value), whilst greatly influencing floral bud development for the next season's crop.

Precocious cultivars grown on dwarfing rootstocks typically produce 3,000-4,000 flowers per tree. Only 200-300 fruit per tree are required for a full commercial crop. Therefore, a ten-fold reduction in flower number is required for a commercial crop of high quality fruit.

Chemical, mechanical and hand thinning are presently used to remove excess flowers and/or fruit. Industry and research experience with these technologies has shown it is difficult to achieve target fruit numbers per tree accurately and repeatedly because:

- Chemical thinning responses are unpredictable from year to year and achieving accurate fruit numbers per tree depends on many variables that influence the thinning response, and environmental variables cannot be controlled by the grower.
- Hand thinning is expensive and its success depends on capable staff, supervision and intensive quality control of work to ensure the desired fruit number per tree is being set.
- Despite combinations of mechanical, chemical, and hand thinning, biennial bearing still regularly occurs in apple orchards and remains difficult to control, suggesting new approaches are required.

Why use Artificial Spur Extinction?

ASE removes a large proportion of the buds just before bud break, enabling tree reserves and resources to be used largely to support the initial growth of the retained floral buds, i.e. those already chosen by ASE to bear fruit through to harvest. Hence trees with ASE management commence spring growth in an already significantly 'crop thinned' state. This enables early flower and fruit development to occur under conditions of much reduced competition than is usual – a factor known to be essential for optimising individual fruit growth.

Trees managed by ASE have much less initial floral and fruit load so do not typically express late fruitlet drop, unlike normally-managed trees. Without the need to wait for fruit drop, growers can make final hand thinning adjustments to set total numbers of fruit per tree at a much earlier stage of fruit development, thereby maximising return bloom, fruit size and quality potential.

Through the process of ASE, floral buds of inferior quality or in positions with poor light are selectively removed. Because ASE provides a lower overall canopy spur density, light distribution into the canopy is improved and usually improves fruit colour and quality.

ASE eliminates the need for chemical thinning and simplifies hand thinning because fruit bud number and spacing have been already set, leaving hand thinners to focus solely on breaking up fruit bunches and removing fruit with defects.

Figure 2: *Measuring the branch basal cross-sectional area (BCA) is done easily using simple branch size gauges.*

Applying ASE to apple trees

When introducing ASE to an orchard block, ensure the block is entering an 'on-cropping year' i.e. expected to flower strongly.

Step 1: Winter pruning

Undertake winter pruning to achieve the correct tree structure (refer to 'Manipulating apple tree structure to optimise fruit yield and quality', *Australian Fruitgrower*, May 2014):

- Retain six branches per metre of canopy height.
- Tie down any upright branches to slightly pendant positions to control vigour and spur development.

Step 2: Determine floral spur density

Determine the target floral spur density to match the crop load required for the target fruit size:

- Measure the branch cross-sectional area (BCA) 2-3 cm out from the base of every limb using a branch size gauge *(Figure 2)*. Then, calculate the total BCA of the tree by summing the BCAs of all its branches. In fully-grown 'tall spindle' trees on 'M.9' rootstock, pruned correctly, a typical total BCA is around 45-50 cm^2. For 'tall spindle' trees on 'MM.106' at lower planted densities, total BCA is typically 55-65 cm^2.

Table 3. Apple fruit bud densities set in winter using artificial spur extinction and corresponding fruit density after hand thinning, fruit weight and yield achieved with artificial spur extinction in PIPS Tree Structure studies on 'Galaxy' on MM.106 and 'Rosy Glow on M.9 located in Shepparton, Victoria, 2013

Fruit bud density set per limb	Total BCA per tree	Fruit density after hand thinning	Mean fruit weight (g)	Trees / hectare	Gross Yield (t /ha)
'Galaxy' / MM.106					
4 buds / cm^2 BCA	63.3 cm^2	4.1 fruit / cm^2 BCA	185.8	1111	55.6
5 buds / cm^2 BCA	55.7 cm^2	4.5 fruit /cm^2 BCA	165.7	1111	48.8
'Rosy Glow' / M.9					
5 buds / cm^2 BCA	39.1 cm^2	5.4 fruit / cm^2 BCA	180.5	2222	83.0
6 buds / cm^2 BCA	45.5 cm^2	5.7 fruit /cm^2 BCA	174.1	2222	101.9

PIPS research shows that commercial crop loads require a spur density in the range of 4-5 buds per cm^2 BCA for 'Gala' types, and 5-6 for 'Cripps Pink' types, based on typical industry target fruit sizes *(Table 1)*. For the chosen spur density, multiply by the tree total BCA to calculate the potential fruit number per tree.

For example 5 buds per cm^2 x 50 BCA = 250 fruit per tree

It is useful to compare the potential fruit number per tree against historical data for the block. Also, check total BCAs against the range suggested above (and shown in Table 1), as too high (common) or too low total BCA indicates pruning for tree structure is not optimised.

Important points to note in Table 1:

- The fruit bud density set by ASE (column 1) is very close to the actual fruit density achieved after hand thinning (column 3), indicating very little labour for hand thinning is needed.
- Mean fruit weight is increased at lower bud/fruit density, the typical crop load response.
- Yield potential is determined by the combination of fruit density and total BCA.

Step 3: Set up reference trees

Retain roughly the same number of buds per tree as the expected final number of fruit per tree, with every branch thinned to the same floral bud density (i.e. the aim is to achieve the same uniform crop density on every branch):

- Shortly before bud break, apply ASE accurately to several representative trees in the orchard, which will act as references for both managers and orchard workers.
- Measure the individual branch BCA, and calculate the number of spurs required using the chosen spur density.
- Thin spurs down to the number required, calculated from the chosen spur density, spacing spurs along the branch and selectively retaining strong, large spurs and short-medium bourse shoots whilst removing weak, crowded and poorly-located spurs especially those on the underside of branches *(Figure 3)*.
- Complete every branch on the tree, moving systematically from the lowest branch upwards *(Figure 4)*.

Step 4: Convert to ASE

Orchard workers do not measure the size of individual branches when they apply ASE to the remaining trees in the orchard. Instead, grower/managers demonstrate how to select spurs and their spacing along the branches to staff, using the reference trees they set up. Depending on the target spur density, it typically equates to around one bud every 8 – 12 cms. Simple rules for ASE are devised by the manager for workers e.g. one hand width between spurs along the branch.

__Figure 3:__ A branch in the upper canopy before (left) and after (right) where artificial spur extinction is set to a floral bud density of 5 buds per cm^2 BCA. The branch cross-sectional area is slightly greater than 1cm^2, requiring six floral buds to be retained, which is a 50% reduction in bud number from the natural bud density. Note the spatial distribution of spurs for maximum light exposure including reducing the double bourse shoot spur (upper centre) from two to one shoot.

Figure 4: *These differences in apple floral bud density and distribution after application of artificial spur extinction provide a visual contrast, photographed within minutes of each other in the same block. The spatial array of spurs using ASE ensures a high light environment from early in the season for all buds. Note upright branches tied to slightly pendant orientation in ASE trees as part of overall canopy control and management.*

Figure 5: *A visual representation of the excessive bud and flower density on a branch of an unmodified apple tree at full bloom (top) compared with an equivalent tree that has received artifical spur extinction set at a density of 5 buds per cm² BCA (bottom).*

Quickly rubbing secateurs along the bottom of each branch to remove underside buds in shaded areas will typically account for two thirds of the bud removal required. Thereafter, simply thin out dense areas of spurs to the agreed spacing, simplifying multiple bourse shoots to single shoots, simplifying complex multi-bud spurs, always removing the weakest buds *(Figure 3)*.

Grower/managers should monitor staff so they do not drift from the target spur density by periodically **measuring** the bud density on random branches and checking against the target spur density and reference trees.

Removal of one-year axillary floral buds – these buds are small, develop later and have inferior fruit – is quickly done at tight cluster stage by stripping off all floral buds by running loosely-pinched thumb and forefinger down one-year-old shoots. *Figures 5 and 6* show the differences at full bloom between trees managed conventionally and trees managed using ASE.

Figure 6: *Profound differences in flower load are evident between conventionally-managed apple trees (left) and trees managed with artificial spur extinction (ASE; right) at full bloom. For cultivars with excessive flowering of buds on one-year-old wood, ASE management includes a rapid easy stripping of axillary floral buds at tight cluster stage of development (right).*

Future articles from the PIPS Tree Structure project will cover the aspects of fruit set responses to artificial spur extinction, architectural responses of trees when managed using ASE for crop load management, practical aspects of crop thinning and setting final crop load and the effects of ASE on return bloom and regular cropping.

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