Scientia Horticulturae 164 (2013) 172–177

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

# Effects of girdling on fruit abscission, yield and shoot growth in macadamia

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ARTICLE INFO

*Article history:*
Received 24 May 2013
Received in revised form 4 September 2013
Accepted 6 September 2013

*Keywords:*
Pruning
Fruit set
Carbohydrates
Tree size
*Macadamia integrifolia*

ABSTRACT

In Australian macadamia (*Macadamia integrifolia* Maiden and Betche, *M. tetraphylla* Johnson and hybrids) orchards, trees are generally side-hedged in early spring to maintain the inter-row for efficient orchard management. Hedging at this time increases fruit abscission and decreases yield due to competition for carbohydrates between fruit and post-pruning shoot growth, and to the loss of photosynthetic area. Girdling increases fruit set in many crops and the possibility that girdling might mitigate the effect of pruning on fruit abscission and yield was investigated in this study. Girdling was also investigated for its potential to control shoot growth and tree size. In the first experiment, in early spring around anthesis, trees were pruned (P), pruned and girdled (PG), or were left as unpruned and ungirdled control trees. Fruit per raceme over time, percent of racemes with fruit at 20 weeks post anthesis, fruit number per tree, nut weight, yield, and the shoot length and number of the post-pruning flush were measured. In a second experiment, trees were pruned (P) or pruned and girdled (PG) in autumn, and the shoot length and number of the post-pruning flush were measured. In a third experiment, trees were girdled at anthesis in 3 years over a 4-year period and shoot growth, tree height, yield, fruit number and nut weight were compared with ungirdled control trees. Girdling mitigated the effect of pruning on fruit abscission and yield but the mitigation was slight with PG trees producing 28% less yield than unpruned control trees. Girdling reduced shoot length and number but more so on unpruned branches (26% and 28%, respectively) than on pruned branches (10% and 14%, respectively). The tree height increment in girdled trees was around half that of ungirdled trees. In the 4-year study, girdling increased yield by around 10% in two out of four seasons, and decreased it in one season. Cumulative yields were similar for girdled and ungirdled trees. This study has shown that girdling was not useful in mitigating the effect of pruning on yield. However girdling was effective in controlling shoot growth and tree size, with no reduction in cumulative yield, and may be useful as a tree size control strategy. Further monitoring of long-term effects of repeat girdling is required to confirm this.



## 1. Introduction

In Australian macadamia (*Macadamia integrifolia* Maiden and Betche, *M. tetraphylla* Johnson and hybrids) orchards, trees are commonly side-hedged in early spring, around flowering, to maintain access, light penetration for ground-cover growth to control soil erosion, and spraying efficiency. However, hedging at this time reduces yield (McFadyen et al., 2005, 2013) due to an increase in fruit abscission caused by competition for carbohydrates between young fruit and the developing post-pruning flush, and a decrease in carbohydrate supply following the loss of canopy (McFadyen et al., 2011). Pruning earlier or later than anthesis, and thereby avoiding depletion of carbohydrate levels during the premature fruit drop period, reduces the yield penalty associated with pruning (McFadyen et al., 2012). It is also possible that girdling trees to increase assimilate availability for fruit growth may mitigate the effect of pruning on fruit abscission and yield.

Girdling involves the removal of a narrow ring of phloem from around the branches or tree trunk thereby blocking the basipetal flow of assimilates without directly affecting the supply of water and minerals from the roots to the canopy. Assimilates and plant growth regulators (PGRs) accumulate in the canopy above the girdle potentially affecting a range of plant processes, including fruit set (Goren and Monselise, 1971; Ruiz et al., 2001; Goren et al.,

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0304-4238/$ – see front matter. 
http://dx.doi.org/10.1016/j.scienta.2013.09.006

2004; Rivas et al., 2006). Trunk girdling has increased fruit set in a number of crops including apple (*Malus domestica* Borkh.) (Hoying and Robinson, 1992), *Citrus* (L.) (De Lange et al., 1974; Barry and Bower, 1997; Rivas et al., 2006, 2007) and lychee (*Litchi chinensis* Sonn.) (Roe et al., 1997). In macadamia, a 1 mm girdle applied to tree trunks did not increase yield (Stephenson et al., 1989). However, this may have been due to the narrowness of the girdle and early regeneration of the phloem. In general, the duration of the effect increases with the width of the girdle (Goren et al., 2004). Branch girdling studies in macadamia by Trueman and Turnbull (1994) and Williams (1980) demonstrated increased fruit set using girdle widths of 10 mm and 30 mm, respectively, although the effect was not significant in the latter study. Girdling in macadamia delayed the onset of carbohydrate depletion that was associated with periods of shoot growth (Cormack and Bate, 1976). This supports the idea that girdling could mitigate the competition for carbohydrates between young fruit and the developing post-pruning flush.

Girdling is also of interest because of its potential to reduce shoot growth and control tree size. In macadamia, this may reduce the reliance on hedging to control tree size for efficient orchard management. Reduced shoot growth in girdled trees has been demonstrated for apple (Hoying and Robinson, 1992), lychee (Menzel and Simpson, 1987), peach (*Prunus persica* (L.) (Allan et al., 1993; Cutting and Lyne, 1993), persimmon (*Diospyros kaki* Thunb.) (Choi et al., 2010) and olive (*Olea europaea* L.) (Proietti et al., 2006). The effect may be due to a reduced supply of PGRs from the root to the shoot following a reduced supply of photosynthates and/or PGRs from the shoot to the root (Dann et al., 1984; Cutting and Lyne, 1993; Goren et al., 2004). Alternatively, as proposed by Skogerbø (1992), the effect may be more localised, proximal to the girdle, because it is evident on girdled branches as well as on trees that have been trunk girdled. Skogerbø (1992) suggested that the effect of girdling on vegetative growth may be due to the accumulation of auxin above the girdle imposing apical dominance on shoot apices.

The objectives of this study were twofold: first, to investigate the possibility that girdling could mitigate the effect of pruning on fruit abscission and yield; and second, to assess girdling as a tree size control strategy in the canopy management of macadamia. We report the effects of girdling on fruit set, yield and the post-pruning flush in one season; and the effects of repeat girdling over four seasons on yield, nut characteristics, shoot growth and tree height.

## 2. Materials and methods

### 2.1. General

The experiments were conducted on '849' (*M. integrifolia*) trees located at the Centre for Tropical Horticulture at Alstonville in northern New South Wales (28.9°S, 153.5°E) on a deep, well drained reddish-brown clay soil (Morand, 1994). The climate is subtropical. The mean maximum temperature ranges from 18.6 °C in July to 27.2 °C in January, and the mean minimum temperature ranges from 9.9 °C in July to 19.5 °C in January. The mean annual rainfall is 1825 mm (Bureau of Meteorology, n.d.). The trees were girdled using a small electrical router (Ryobi EVT400K, Techtronic Industries Australia Pty Ltd., Doncaster, Victoria, Australia) to remove a ring of bark, 6 mm wide, from around the whole trunk.

### 2.2. Experiment 1: girdling and pruning trees at anthesis in early spring, 2008

The trees in this experiment were planted in 2002. Forty-two trees over four rows were divided into fourteen 'blocks' of three trees each. Ten racemes on each tree were tagged prior to anthesis. Two trees in each block were tip-pruned during anthesis on 19 August 2008 to simulate hedging. Tip-pruning involved removing the most recently matured flush with a motorised pole hedger or hand held secateurs. One of the pruned trees in each block was girdled on the 21 August 2008 and the third tree in each block served as the control and was left unpruned and ungirdled. Treatments were randomly allocated to trees within each block.

After pruning, 10 branches near the top of each tree were tagged. When the post-pruning shoot growth had fully elongated, these branches were removed from the tree and shoot number, length and dry weight were measured.

Fruit per raceme were counted on 16 September 2008 and then weekly until 27 October 2008 and then fortnightly until 20 January 2009.

Fruit were harvested from the ground and stripped from the tree on 11 March 2009. Subsamples of 100 nuts were taken from each tree to determine nut weight and moisture content, and yield was expressed as nut-in-shell at 10% moisture content. Fruit number per tree was estimated from the total weight of nuts per tree and the average individual nut weight.

### 2.3. Experiment 2: girdling and pruning trees in autumn, 2009

In Experiment 1, much of the post-pruning shoot growth was stunted by thrips (*Scirtothrips* sp.). We were concerned that this would mask any treatment differences in shoot growth and so we pruned and girdled more trees in the same planting in March 2009. Twenty trees across three rows, adjacent to the rows that contained Experiment 1, were grouped into 10 pairs. All trees were pruned on 16 March 2009 as described for Experiment 1, and one tree in each pair was girdled on 18 March 2009. After pruning, branches were tagged and shoots were measured as described for Experiment 1.

### 2.4. Experiment 3: girdling trees at anthesis, 2008, 2009 and 2011

This experiment was carried out on trees planted in 1998. Trees were girdled during anthesis on 28 August 2008 and 1 September 2009, allowed to rest in 2010, and girdled again during anthesis on 19 September 2011. Ungirdled trees served as controls. Treatments were randomly allocated to paired plots, which each comprised three trees. Eight replications per treatment were distributed across 10 rows. Plots were buffered within the row and in adjacent rows by untreated '246' (*M. integrifolia*) trees.

Ten branches at the top of each tree were labelled shortly after the first and second applications of girdling, and the presence, length, and shoot number of new flushes (since girdling or the previous measurement date) were measured on 16 February 2009, 11 August 2009, 2 February 2010 and 30 August 2010. In September 2010, another 10 shoots at the top of the tree were labelled and the same measurements were made on 31 May 2011. Tree height was measured just before the first girdling, and then at approximately 12-month intervals up to July 2012.

Standard side-hedging with a commercial hedging machine to maintain the inter-row for orchard management was applied to both treatments on 23 November 2009 and 12 September 2011.

Fruits were harvested from the ground at 3- to 4-week intervals between March and September from 2009 to 2012. Subsamples of 100 nuts were taken from each plot at each harvest to determine nut weight and moisture content, and yield was expressed as nut-in-shell at 10% moisture content. Fruit number at each harvest was estimated from the total weight of nuts and individual nut weight, and this estimate was used to calculate a weighted average nut weight for each plot for the season. At the second harvest in each season, the 100-nut sample was also used for the determination of nut quality as described in McFadyen et al. (2004).