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Bark ringing in fruit crops - A review

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Abstract

Bark ringing or Girdling, a horticultural technique involving the removal of a strip of bark around the trunk or branches of fruit trees, has been widely studied and utilized to influence various aspects of fruit crop management. This practice primarily enhances fruit production, regulates canopy growth, and improves fruit quality. By interrupting the downward flow of nutrients and hormones, girdling can stimulate root development in hardwood cuttings and modify vegetative growth patterns. For instance, it has effectively reduced canopy shoot growth in vigorous apple cultivars, thereby improving fruit yield and quality. Additionally, girdling techniques such as notching and scoring control shoot growth and promote scaffold development in young trees. The method also has implications for nutrient distribution, as it can impact the formation of callus tissue and affect recovery processes. Despite its benefits, girdling can lead to undesirable outcomes, such as basal sprouting below the girdle. This abstract summarizes the critical applications, effects and considerations of girdling in fruit crop management, highlighting its role in optimizing fruit production and tree health.

Keywords

girdling; bark ringing; bark; canopy management; fruit production

Introduction

Girdling, or ringing, is a widely practiced horticultural technique used in many fruit crops to manipulate tree growth and development. It involves removing a strip of bark from the trunk or major limbs of a fruit tree, which blocks the downward movement of photosynthates and metabolites through the phloem (Fig.1). This interruption in phloem transport leads to increased levels of foliar carbohydrates (sugars and starch) and plant hormones above the girdle, promoting flowering.

Ringing or Girdling

Girdling is a well-known method for stimulating fruit bud formation in plants. Girdling, or ringing, is a horticultural technique where a strip of bark is removed from a tree's trunk or branches, blocking the flow of nutrients and sugars (Table 1). This causes sugars to accumulate above the girdle, stimulating growth and flowering, especially in fruit trees.

Indeed, while girdling is an age-old horticultural practice, its use has not been universal across all crops. However, shifting trends from chemical-based agriculture to more sustainable practices, like green farming, have prompted farmers to seek less harmful methods to the environment and leave minimal chemical residue on fruits. Additionally, fruit producers continually search for ways to lower operational costs while upholding fruit quality standards. Girdling is a captivating method with various uses in

Fig. 1. Mango tree was undergirdled by using the tool sickle at the width of 2mm.

horticulture and forestry. It disrupts nutrient flow through the phloem, causing nutrients to accumulate above the girdle and triggering different plant responses. In horticulture, girdling is commonly used to improve flowering, fruit set and size (Table 2).

Studies by (1) and (2) have revealed that girdling can enhance leaf nitrogen content, change the C/N ratio, and boost carbohydrate concentration, thus promoting flowering and fruit growth. It can also reduce fruit drop, increase chlorophyll levels and improve photosynthetic efficiency. Combining girdling with practices like potassium spray, as shown by (3), can improve fruit yield and quality. Girdling is also employed to hasten fruit ripening and induce flowering in excessively vigorous trees like mangoes. Girdling serves different purposes in forestry, including altering wood properties by affecting nutrient allocation and cambial activity. Overall, girdling is a versatile tool for manipulating plant physiology to achieve desired outcomes in horticulture and forestry, underscoring its significance in modern agricultural practices.

(4) conducted girdling experiments on peach and nectarine trees by carefully removing a strip of bark from around the trunk or the base of each scaffold limb using a grape girdling knife. The width of the cut was either 1/8 or 3/16 inches, and it was made only as deep as the cambium layer, the region between the bark and wood. They observed a temporary disruption in the downward flow of carbohydrates in the phloem, making them more accessible for fruit growth and development. They cautioned that if the cut is not sufficiently deep, the uninterrupted downward flow of nutrients will persist, resulting in no response from the fruit. However, deeper cuts that penetrate past the cambium into the xylem tissue disrupt the upward flow of water and nutrients, causing severe stress and potential death of the limb or tree. For girdling to be effective, the cut must encircle the limb entirely, with the two ends meeting or overlapping in a spiral pattern. Even leaving a small section of bark intact can allow enough phloem to remain for the downward flow of carbohydrates to continue, rendering the girdling ineffective.

Table 1. Description of Girdling techniques

Techniques	Functions	Reference
Girdling	Removal of a strip of bark from the trunk or major limbs of a fruit tree, thereby blocking the downward translocation of photosynthates and metabolites through the phloem.	(4)
Cincturing	Making a slit that is entirely perforated around the target branch or trunk	(90)
Double girdling	Typically, in various locations throughout the tree	(49)
Guillotine girdling	The tree trunk's diameter was divided in half by two opposing, deeply cut horizontal chainsaw cuts, spaced 20 centimetres apart vertically.	(91)
Ring-girdling	Two opposing half-circle cuts that were 20 cm apart vertically were made in the tree's trunk.	(92)
Chemical girdling	Painting the trunk with a ring made of chemical solution or morphactin.	(93)
Hot girdling (Steam)	A burst of steam encircling the petiole or stem	(94)
Hot girdling (wax collar)	Warm wax (between 80 and 85°C) filled in a wooden collar and sealed around the petiole	(95)
Cold girdling	The layer of the cold jacket was placed over the petiole and circulated ethanol/water combination to chill it down by 1-3°C	(6)
Hacking or frilling	Toxic compounds can be injected into the frill created by a single line of overlapping downward axe cuts.	(96)
Notching	Slicing into the sapwood and removing a bark fragment that is right above a bud	(97)
Ringing	The process in which a circular ring of bark is removed. It hastens bearing by allowing greater.	(98)
Scoring	Remove the bark but leave the bark tissue intact by making a single, narrow cut around the trunk.	(99)
Strangulation	Using a steel wire to depress the bark and adjusting the depth and tension as needed	(100)
Stripping	Removing a section of the tree's bark all the way around. Same with girdling, yet it was noted that piercing the sapwood may be a factor.	(55)
Wiring	Strangulation-like depressing of the bark with a steel wire, adjusted for depth and tension	(55)

Table 2. Details of Girdled fruit trees and their Season, Width, Fruit Weight, Percentage of Fruit weight, Fruit yield and the percent age of Fruit yield.

Fruits	Season	Girdled/ Control	Girdling Width	Fruit Weight (g)	Percentage of Fruit Weight	Fruit Yield (Kg)	Percentage of Fruit Yield
Mango	Mid-April	Girdled	1.5cm	300.75	80	97.42	90
		Control	-	120.22	65	56.23	78
Litchi	September	Girdled	4 mm	136.02	66	30.41	78
		Control	-	75.00	45	16.90	65
Grapes	December	Girdled	1 cm	530.43	85	250.33	90
		Control	-	200.79	75	120.00	80
Citrus	March	Girdled	4 mm	144.44	72	69.93	86
		Control	-	100.54	67	51.90	72
Apple	May	Girdled	2 cm	240.90	77	94.50	92
		Control	-	95.00	51	49.51	64
Pear	May	Girdled	1.5 cm	220.87	77	90.56	83
		Control	-	110.12	59	44.89	66

Girdling concepts and techniques

The type of girdling used, particularly its width, is crucial and should be chosen based on the desired outcomes (5). Regular horticultural girdling procedures should avoid damaging the cambium or deeper tissues (6-8). Damage to the cambium disrupts the formation of callus bridges over the exposed area, while xylem damage impedes the water and mineral supply to the canopy. Additionally, xylem damage can hinder the full recovery of the affected area ((9) (7)) (Fig.2).

A. Site of Girdling

The question often arises whether girdling the trunk versus girdling the main branches yields identical effects. For example, cane girdling produced better results in grapevines than arm or trunk girdling (10). However, in general, all girdling sites tend to yield comparable outcomes. It is essential to consider the tree's susceptibility to girdling; if there is a risk of severe damage, girdling should be applied to the foremost limbs, leaving one or two limbs ungirdled ((11) (12). This partial tree girdling helps prevent root starvation and reduces potential damage. It's common practice to girdle only half of the limbs in shy-bearing avocado trees every year (12).

B. Morphology of the Girdle

Morphological changes resulting from girdling were observed in citrus (13) and peach (14) trees, both above and below the girdle on the trunk and in the roots below the girdle. Degeneration of sieve tubes and companion cells was noted, accompanied by hypertrophy near the girdle and similar damage extending further from the wound (13). Phloem degeneration occurred within two weeks when girdling was conducted in July, but it took nine months for similar changes to manifest when girdling was performed in October (13).

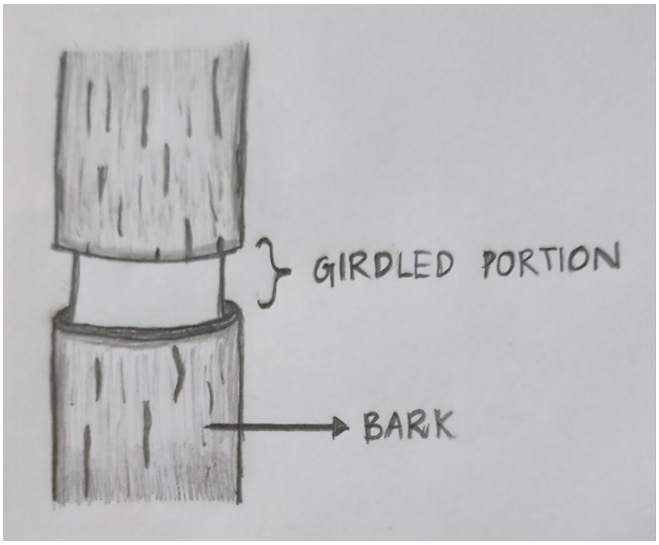

Fig. 2. The picture of the girdled portion after girdling

The width of the girdling ring is another crucial factor to consider. For instance, a 3 mm ring caused partial death of summer branches in pistachio trees due to the slow closing rate of the girdled area (15). In grapevines, scoring was significantly less effective for increasing berry weight than a 4.8 mm wide girdling (16). However, girdles up to 5 mm in width did not damage Shamouti orange trees when treated at various times throughout the year (17). Generally, a wider ring provides a more prolonged effect but also increases the risk of damage to the tree (18). Therefore, relatively wide ringing should only be applied to strong and vigorous trees capable of withstanding the treatment (11) (19-21).

C. Healing

Healing the wound and re-establishing normal connections between the root and canopy are crucial for the future health of the branch or tree. This healing process involves regenerating the vascular connection, which relies on cambial activity. Therefore, it is essential to avoid damaging the cambium.

The effectiveness of girdling depends on how long it takes for new callus bridges to form across the ring. Callus develops at the edges of the cut surface and gradually covers the entire exposed area (22). In peaches, callus growth is most noticeable from the upper edge of the girdle downward (23). Conversely, apples form a minimal callus at the distal end of the girdle. The cambium starts to develop within this callus, with callus cells transforming into cambial cells where they contact the intact vascular cambium. This process, similar to closing a diaphragm, involves the callus cambium differentiating from all edges of the wound toward the center (24). The new vascular cambium then produces a xylem and phloem that align with the existing tissues in the unaffected part of the stem. A periderm forms in the outer part of the callus, matching the original stem periderm, if present (22).

In citrus, new callus bridges typically appear about three weeks after girdling, coinciding with the recovery of respiration levels and the stabilization of starch levels (25). For grapes, callus bridges develop 16 days after girdling, with phloem elements becoming visible shortly afterwards (26). In sugar maple, the formation rate of the xylem and phloem elements in the girdled area is influenced by the season in which girdling occurs (27). Since vascular element differentiation in the callus relies on cambial activity, it takes longer for elements to form during dormancy than periods of high cambial activity. Therefore, it is preferable to girdle during active growth periods when callus bridge formation is quicker.

Additionally, humidity affects recovery rates; using plastic strips to wrap the girdle can help maintain humidity. Keeping the cambium moist will encourage immediate callus production and phloem replacement. Various chemicals and sprays can be applied to promote healing and recovery after girdling. These treatments help protect the exposed tissues and stimulate the healing process. Common options include:

1. Plant Growth Regulators: Auxins (e.g., IAA - Indole-3-acetic acid): These hormones can help stimulate cell division and differentiation, aiding callus formation and tissue repair. **Gibberellins**: These can promote cell elongation and growth, supporting the development of new tissue.

2. Wound Dressings: Tree Wound Paints: Specialized paints or coatings are applied to the girdled area to protect it from pathogens and environmental stress. They often contain compounds like latex or tar. **Sealants**: Products such as pruning sealants or grafting wax can cover the girdled area, preventing infection and moisture loss.

3. Fungicides: Copper-based Fungicide can help prevent fungal infections at the wound site. **Systemic Fungicides**: These are absorbed by the plant and can protect against various fungal pathogens.

4. Antibiotics: Streptomycin or other antibiotics: These can be used in certain situations to prevent bacterial infections at the wound site.

5. Nutrient Solutions: Fertilizers: Applying balanced fertilizers or specific nutrient solutions can support overall plant health and recovery, ensuring the plant has the nutrients for wound healing.

6. Hydration Solutions: Humidifiers or Watering: Maintaining adequate soil moisture can help reduce stress and support plant recovery.

Girdling in Horticultural practice

A. Floral Induction

Girdling and similar methods have been utilized to prompt earlier flowering in young apple trees, showing notable effectiveness, especially in trees about to flower or those already showing some flowers (28). (29) Found that scoring apple seedlings aged 4 to 7 years was more successful in inducing flowering than scoring 3-year-old seedlings. Girdling branches of mature apple trees notably increased the formation of flower buds (30). However, applying rings between May 30 and July 30 inhibited flower formation in the subsequent year (31). The induction of flower formation was observed as a gradual process, reaching its peak in mid-June and completing by late July. Consistent scoring of 'Delicious' apple trees for three consecutive years resulted in reduced terminal growth and increased yield during the second and third years (32) (Fig.5). The stimulation of flowering through girdling may be attributed to the necessity of reaching certain carbohydrate levels in the canopy for flower formation (33). Bernier and colleagues have suggested a role for sucrose in the floral induction of *Sinapis alba* (34) (35).

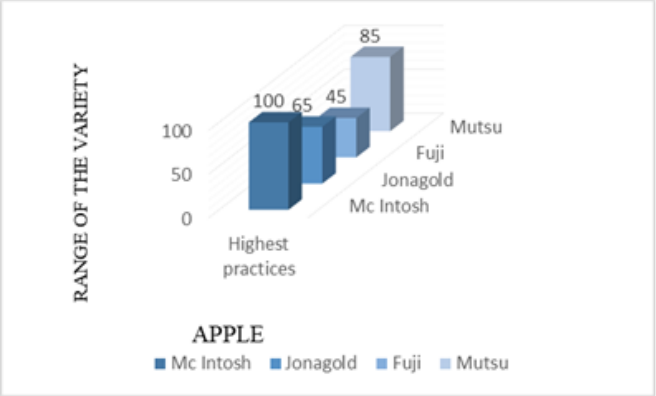

Fig. 5. Top girdled variety of apple

B. Fruit Set

Fruit set plays a crucial role in crop yield, with the persistence or shedding of young fruitlets being a significant physiological event influenced by various internal and external factors (36). Girdling enhances fruit set in many tree crops primarily by reducing fruitlet shedding, as observed in citrus (37-39), apple (30, 40, 41), olive (42) and persimmon (43). Similar effects have been noted with the strangulation of citrus trees in early spring (44). However, girdling to enhance fruit set in avocado is typically performed during the preceding autumn (45).

Carbohydrate levels significantly limit fruit set (36, 46, 47). Girdling induces the accumulation of carbohydrates in the canopy, potentially enhancing fruit set by supplying more carbohydrates to the reproductive organs. In avocados, girdling has been observed to elevate carbohydrate levels in the pistil (45). Studies on cultured flowers have shown that adding sugars to the medium enhances the growth of pollen tubes and their penetration into the ovule. This suggests that in avocados, girdling may influence fruit set by boosting carbohydrate levels in the pistil, thereby promoting faster pollen tube growth (45).

Moreover, the involvement of plant hormones in fruit set processes is well-established (48) (6). Therefore, the impact of girdling on fruit sets may also entail changes in hormonal balance. Indeed, applying gibberellins is frequently combined with girdling to ensure sufficient fruit set in grape (49) and citrus (6, 50). In citrus, girdling may enhance yield even when performed during the fruitlet abscission period by reducing the final stages of fruitlet drop (51).

C. Fruit Size

The beneficial impact of girdling on fruit size is extensively documented and widely practiced in various fruits. Girdling has been notably effective in enhancing fruit size in grapes (52-55). Similarly, studies have shown girdling-induced enlargement in fruit size in peach (56-58), nectarines (18, 59, 60), mango(61) (62), avocado (63), olive (63-66) and persimmon (43) (67). However, girdling appears to have a lesser impact on fruit size in apples (68-70). Girdling, a technique applied post-fruit set in grape vines and at specific stages in other fruits like peach and nectarine, consistently boosts fruit size by enhancing the supply of photosynthates. It's often combined with treatments like GA_3 and has shown significant increases in fruit weight across various fruits. Double girdling methods have been particularly effective, indicating its potential for enhancing fruit size and yield in citrus varieties like clementine.

D. Yield

Increasing yield is a primary objective in fruit tree cultivation, achieved through increased fruit number and larger fruit size. Girdling is a common technique used to enhance yield in various tree crops, particularly in cases where the natural yield is low, such as in young trees or orchards with alternate bearing patterns. However, excessive fruit numbers can lead to a surplus of small, low-value fruits, often necessitating thinning. This situation is common in crops like grapes and tangerine hybrids, where girdling may be required to ensure adequate fruit set, followed by thinning to achieve desirable fruit size (49, 71).

Girdling practices in fruit crops

Mango

Ring barking has been done in the mango cultivar "Alphonso" to increase the blossom. According to the trial results, the highest reported fruit yield per tree, fruit number per tree, and fruit output per hectare rang in the first two weeks of May and September. (72) (73). For this investigation, 25 healthy, uniform “Chok Anan” mango trees planted using the high-density planting (HDP) method were chosen. The use of foliar spray has been combined with ring barking. The use of foliar spray has been combined with ring barking. This indicates that mango trees flush earlier when the girdling approach is combined with foliar spraying (74). The maximum percentage of fruit set at harvest, fruit weight, pulp volume, number of fruits per shoot, and yield kg per plant were all obtained by girdling on July 15 with a 1.50 cm width (75) in cv. “Ratna”, the tertiary branches were girdled with horticultural techniques like tip pruning (removing new branches) and smudging. It has proved advantageous for promoting early flowering and harvesting (76). (Fig.3).

Litchi

Litchi (Shahi) yielded greater blooming panicle, fruit yield, fruit size, TSS, and TSS/acid ratio when a circular girdling of 2 mm was applied to 50% of the primary branches. (77). Litchi trees were also girdled with varying severity and width and had higher fruit set, retention, and output than the control group. They also had lower fruit drop (78). The practice also reduces the fruit drop and cracking (79). (Fig.4)

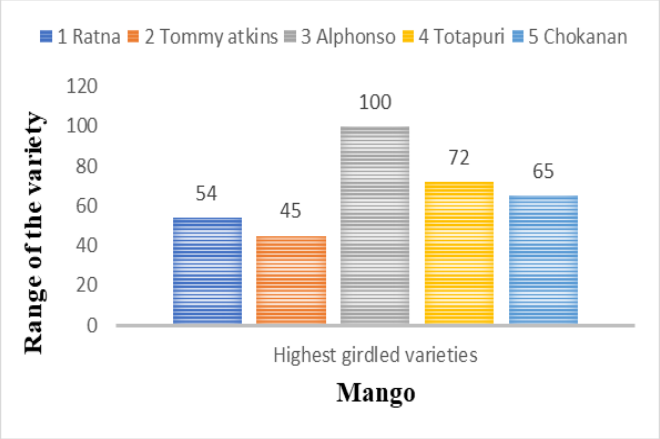

Fig. 3. Top girdled variety of mango

Fig. 4. Top girdled variety of litchi

Citrus

The citrus trees were treated with girdling and gibberellic acid between July and December. In comparison to the control treatment, the best fruit length and diameter were obtained with the girdling 4 mm in December and the girdling 4 mm+50 ppm GA3 treatment (80). Around twelve-year-old Kinnow mandarin trees (Citrus reticulate Blanco) were planted in clay-loam soil, budded on sour orange (*Citrus aurantium* L.) rootstock. Six different treatments were used in the investigation. According to the results, the fruits on light-pruned trees weighted 7.2% less, yet their yield and quantity increased by 170.4% and 191.5%, respectively. In light of the findings, it is advised to employ either girdling or mild pruning alone to boost the fruit set of "Kinnow" mandarin trees (81).

Grapes

An 8-year-old Victoria and Italia table grape varieties were girdled near the cane base to promote berry production and hasten ripening following the application of gibberellins (the end of the fruit set). Depending on the climate of the study year, both girdling and gibberellins (GA_3) have hastened ripening. It is advised to repeat the trial for at least one more season to confirm the results obtained thus far and determine whether the treatments can be improved over time to result in significant differences for early ripening, higher yields and better-quality berries. (82). Thirty Ruby Seedless vines were planted in clay soil with the same age and growth characteristics. Pinching the shoots outperformed all other treatments by a wide margin (83) (Fig.6).

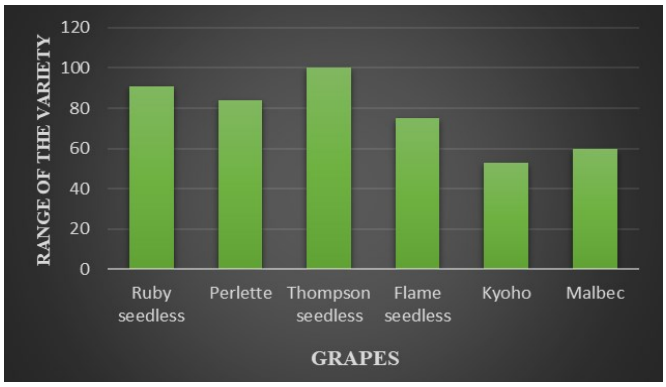

Fig. 6. Top girdled variety of grapes

Kiwi

Two years in a row (2018 and 2019), a 5-hectare kiwifruit orchard in Agrinio County, Western Greece, was girdled at specific times with a girdling cutter. Girdling the trunk or canes in the early stages of fruit development is mainly done to improve fruit size; girdling in the later stages is primarily done to increase fruit dry matter (84). Vines of the kiwifruit cultivar “Allison”, aged ten years, were used in the experiment. Four distinct girdling levels were used in total for the experimental vines, the findings of (85), who said that applying girdling increased the total soluble solids/acidity ratio and hence supplied freshness. According to (86), girdling drastically enhanced sugar reduction and was the most efficient in raising the TSS/acid ratio (87).

Pear

In pear orchards of "Packham's Triumph," trunk girdling is used to reduce the vegetative development of the trees on the vigorous *Pyrus calleryana* rootstock. On robust calleryana rootstocks, the double girdling improved the crop output and crop value of "Packham's Triumph" pears (88).

Olive

The olive cultivars Uslu and Nochlerra were used for girdling, spraying, and controlling salicylic acid, naphthalene acetic acid, and gibberellic acid. The selected olive trees are uniform branches with a 2-3 cm diameter chosen for the canopy (girdling width: 2-3). It shows that there is no such difference was seen for fruit drop percentage and fruit harvest percentage, treatments were found to have a significant impact on the number of inflorescences, flower count, perfect flower percentage, flower drop, fruit set percentage, fruit size, fruit weight, pulp weight and oil contents (89).

Conclusion and outlook

Girdling produces a wide variety of horticultural impacts. As was previously said, factors affect every stage of reproductive development, including flowering, fruit set and development and frequently, fruit maturity and quality. Nevertheless, the process or mechanisms underlying the functioning of girdling remain incompletely understood. Recent advances in plant science suggest that molecular up-and down-regulation of gene activity will likely be involved in plants' responses to agrotechnical treatments. Therefore, it stands to reason that responses to girdling would likewise involve modifications to gene expression. Undoubtedly, this assumption will be addressed in future girdling research.

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Authors' contributions

N: Write the original draft and conceptualize it. NSRVA: Revision of the draft, including tables and figures, and proofreading. NSRVA: Revision, formatting and Supervision. All the authors read and approved the final version of the manuscript.

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Declaration of generative AI and AI-assisted technologies in the writing process

For paraphrasing few sentences, I have used only the Chatgpt AI tool.

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